ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. IV JANUARY–FEBRUARY, 1909 No. 1

THE COAL FIELDS OF ALBERTA.[1]

D. B. DOWLING.

To the roaming savages the burning places on the river banks were no doubt objects of awe to be shown the incoming explorer who could not pass without closer scrutiny. Thus from some of the early travellers comes the information that coal was to be found in the northern interior of this continent. The earliest mention is probably that by Sir Alexander Mackenzie in 1789 announcing the presence of coal seams on Great Bear River. This was followed by a note on Arrowsmith's map of 1811, which gave Mr. Fidler's route across the plains in 1793, to the effect that coal was to be found on the Red Deer River in Alberta somewhere near the mouth of Kneehill Creek or the Rosebud.

David Thompson's journal (unpublished) notes in 1800 that on the Saskatchewan River near Goose Encampment he saw an exposure of bitumen mixed with earth. This by later observers was found to be the outcrop of a seam of lignite 24 feet thick. The coal at Edmonton is noted by Sir George Simpson in 1841 and ten years later Sir John Richardson obtained specimens and considers them to be of the same age as those on the Mackenzie River. In 1845 Father De Smet came across the mountains to Rocky Mountain House on the Saskatchewan and reported coal on one of the branches of Red Deer River near the mountains. Dr. Hector (Sir James) found coal on the Souris River

[1] By permission of the Director of the Geological Survey of Canada.

in 1857, and in the report of the Palliser Expedition describes the coal at Edmonton and mentions that it was used in the forges with success. He also notes the seams on Red Deer River and in the year 1860 saw several seams on the Athabaska River and the seam at the crossing of the Pembina River.

The further history of the finding and mapping of the coal measures of this province runs parallel to the activity in finding railway routes across the continent and opening of means of communication with the older provinces. The geological structure of the area was roughly outlined by Sir James Hector, but to Dr. G. M. Dawson, R. G. McConnell and J. B. Tyrrell fell the lot of making the detailed examinations which give us a true insight into the structure and areal distribution of the measures. The coal is found in three distinct horizons in the Cretaceous, separated by shales of marine origin. The lowest is practically the base of the formation and is considered Cretaceous from its fossil flora, though it lies just above the Ferine shale, now understood to be of Jurassic age. The line of demarcation is not very sharp as the shales in their upper part become interstratified with sands and gradually pass into a sandstone formation containing coal seams—called by Dawson the Kootanie. The age of the Kootanie, if not Jurassic, must be early Cretaceous. Above this the Dakota does not appear to be coal-bearing in an economic sense, and not till near the top of the Belly River or Judith River formation is reached do there appear to have been land conditions of sufficiently long duration for the formation of coal beds. The coal horizon in the Belly River contains but a few workable seams, but its areal distribution makes it important. The third coal horizon is at the top of the Cretaceous and includes part of the old Laramie formation. The upper part in Alberta is a fresh-water deposit and is classed as Tertiary under the name Paskapoo formation, and is not distinctly coal-bearing. What is believed to be the same horizon as the lower Laramie bears many lignite seams and in Alberta is given the name Edmonton formation, the highest member of the Cretaceous.

The three coal horizons are then as below:

Edmonton formation,

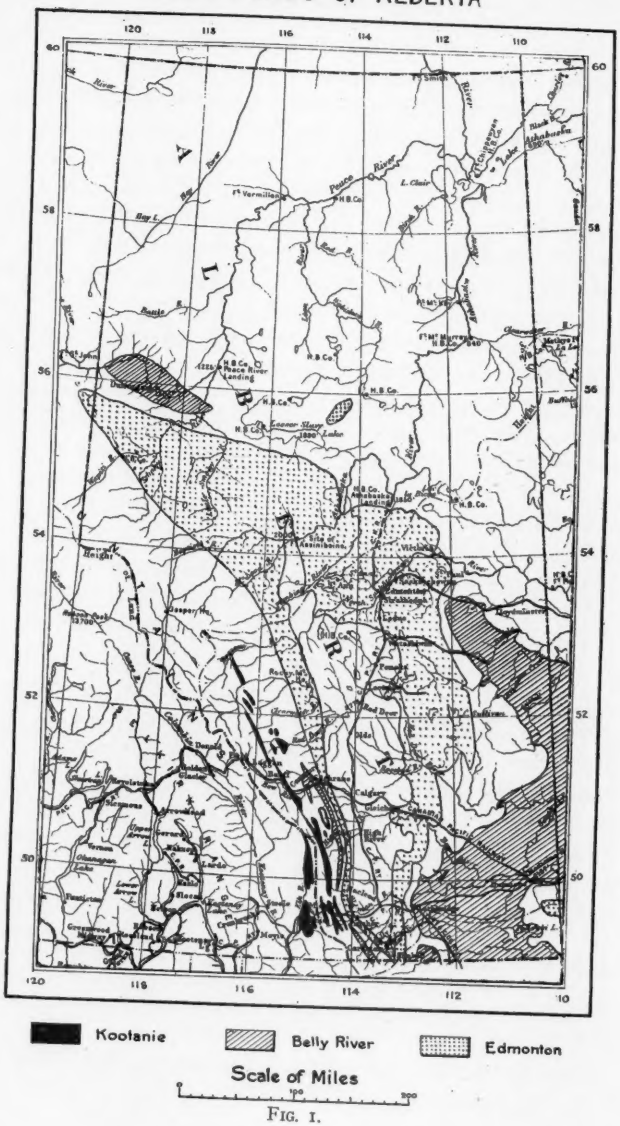
COAL FIELDS OF ALBERTA
Kootanie
Belly River
Edmonton
Scale of Miles

FIG. I.

Belly River (Judith River) formation,
Kootanie formation.

The distribution of these formations may be seen on the accompanying illustration, Fig. 1.

KOOTANIE FORMATION.

This being at the base of the Cretaceous and near the limestone beds which represent the Carboniferous and Devonian, is exposed only in the disturbed areas in and near the Rocky Mountains. The faults and uplifts which bring up the limestones have also elevated these coal measures, but a great portion has been denuded. As the general system of mountain building for the outer ranges of the Rockies is a series of fault blocks dipping generally to the west, these blocks have often remnants on their western slope of the overlying Kootanie formation and the coal measures are generally to be found against the next succeeding fault block. Within the mountains, then, the coal fields are generally in long, narrow strips between the ranges. The thickness of the formation bearing coal reaches a maximum in the Elk River valley of 4,700 feet with twenty-two workable seams and a minimum outside the mountains to the east of only about 200 feet, with two seams. In addition to the Alberta areas the Kootanie formation is also found on the western slope within the Province of British Columbia in what has been called the Crow's Nest area, perhaps the most important coal field of Canada. The workable coal is there estimated at 216 feet over an area of 230 square miles.

The Alberta areas are not so extensive, but are distributed from near the boundary north to near the Yellow Head Pass, and may be discussed under the following general descriptions.

COLEMAN AREA.

A narrow belt crossing the Crow's Nest branch of the Canadian Pacific Railway. Measures dip west and have a coal content of 100 feet coal. The area is about thirty miles long by one and a half wide.

BLAIRMORE-FRANK AREA.

This is east of the Coleman area and is somewhat irregular in shape. The measures are broken by several faults, but there can be assumed a workable thickness of over fifty feet of coal.

In these two areas the coal is a bituminous coking and steam coal, but has from ten to fourteen per cent. of ash.

LIVINGSTONE AREA.

North of the former two noted there is a wide band west of the Livingstone range crossed by the waters of Livingstone, Highwood and Sheep rivers. On each of these streams important coal seams have been discovered and the coal is generally of bituminous character though in places it approaches an anthracite coal.

MOOSE MOUNTAIN AREA.

This is an isolated expanse of limestone in advance of the outer range, and surrounding it there is a narrow ring of the upturned Kootanie formation. In it there are several seams but two of them appear to be workable with thicknesses of seven and eight feet each.

CASCADE AREA.

A long band of these rocks is found in the mountains extending from the Kananaskis River north to near the Saskatchewan. It crosses the Bow River on the main line of the Canadian Pacific Railway near Banff and on it are situated the mines at Canmore and Bankhead. The measures are proved to have from 75 to 100 feet of coal in a total of from 10 to 14 seams. The lower ones in the Bow Valley are in some places anthracite, but the upper ones are more volatile and at Canmore a high-grade steam coal is produced.

PALLISER AREA.

East of the Cascade area, but north of the Canadian Pacific Railway, there are two small areas within the mountains that appear to have coal in amounts sufficient to warrant their being

classed as possible coal fields. The first is not of great extent, but has perhaps a workable seam of five feet in an area of six square miles.

COSTIGAN AREA.

This is larger than the Palliser area, and although the coal seams do not run to much over eight feet, the measures are not greatly disturbed. The coal is at the upper limit of the bituminous class.

BIGHORN AREA.

This lies behind the Bighorn Range which is in advance of the main range and runs only from the Saskatchewan to the Brazeau River. About nine workable seams are known with seventy feet of coal. This is bituminous and probably coking, and as the area is fairly large and easily approached by the Saskatchewan Valley it will shortly be an important field.

ESTIMATE OF AREAS AND COAL CONTENT.

Coleman Area.—Thirty miles long by one and one half wide, forty-five square miles, can be estimated at fifty feet of coal, which would give a total content of 2,000 million tons. The character of the coal can be judged by the following analyses made by G. H. Dickson:

	Thickness.	Moisture.	Volatile.	Fixed Carb.	Ash.
Seam No. 2	16 ft.	0.38	25.02	61.94	12.66
Seam No. 4	6 t.	1.10	17.60	67.80	13.50

Blairmore-Frank Area.—An estimate of fifty square miles for the area with a workable thickness of thirty feet of coal would give a total of about 1,500 millions of tons. The coal is of about the same character as that at Coleman, though in some instances the ash is higher. It is generally classed as a steam coal and the washed coal gives a good coke.

Livingstone Area.—This has not been thoroughly prospected, but on the south branch of Sheep River important seams have been discovered. The area is approximately sixty square miles.

From the exposures known there seems to be about thirty feet of coal in the measures, which would give a coal content on this basis of 1,500 million tons. The character of the coal may be judged from analyses of seams exposed on the south branch of Sheep River as below:

Thickness.	Moisture.	Volatile	Fixed Carb.	Ash.
3′ 0″	0.69	19.98	73.12	6.21
9′ 6″	0.52	13.19	76.00	10.29
8′ 8″	0.72	11.51	74.71	13.04

Moose Mountain Area.—As the exposures are in narrow bands surrounding Moose Mountain, an approximation of the area available depends largely on whether it can be got at. Of the twenty-five square miles which appear on the map perhaps fifteen can be assumed as available with a coal content of fifteen feet. This would give an amount of, say, 150 million tons available coal. The character of this as given by the few analyses we have shows it to be a good bituminous coal.

Locality.	Thickness.	Moisture.	Volatile.	Fixed Carb.	Ash
Sec. 8 Tp. 23 R6	6′ 10″	2.74	18.62	75.52	3.12
Thorne Mine	7′ 7″	6.17	13.54	69.77	15.52
Coxcomb Mt.	3′ 0″	1.64	14.26	82.01	2.09

Cascade Area.—Although there is a total of over one hundred miles for the length of this basin, a part, that between the crossing of the Cascade and Red Deer rivers, is not sufficiently rich in coal seams to be counted. The better part of the coal measures are eroded, so that we can count about forty miles at the south end and about twenty at the north end as rich measures. In the south end of the measures there is over seventy feet of available coal. The lower seams are anthracitic and anthracite and the upper ones probably bituminous in some places.

In the northern portion one section gives eleven seams with ninety-four feet. This is a bituminous coal throughout. The amount of coal of the harder varieties in the lower seams has been estimated at 400 million tons, and for the upper part of the measures in the south and the northern portion considered as bituminous an estimate of 800 million tons would not seem

excessive. This gives a total for the area of 1,200 million tons of coal.

As a few analyses might be interesting, a selection is made to show the range:

Locality.	Thickness.	Moisture.	Volatile.	Fixed Carb.	Ash.
Anthracite Mine	3′ 40″	1.04	9.15	87.18	2.63
Bankhead No. 2	8′ 0″	0.43	10.65	85.02	3.90
Canmore No. 5	5′ 3″	1.10	14.66	78.38	5.20
North of Red Deer, Seam No. 10	11′ 0″	1.20	19.61	74.17	5.02

Palliser Area.—This is divided by Panther River into two portions. A five-foot seam has been found that could be depended on for a small area and a total coal content of twenty million tons should be available. The coal of the five-foot seam is of excellent quality, though not a coking coal. The analysis of this seam is as below:

Moisture	Volatile.	Fixed Carb	Ash.
0.93	10.58	83.55	4.94

Costigan Area.—The measures occupy a triangle of which one side—the western—is upturned, forming a trough with gently sloping measures over most of the area. Two workable seams are known with coal that is about the same character as at Canmore—steam coal that is hard to coke. The area available is about twelve square miles, and estimated at eight feet of coal would give about sixty million tons.

Bighorn Basin.—The area over which the measures outcrop is about thirty miles in length and as one section has shown about sixty feet of coal in workable seams an estimate of available coal based on an area of thirty square miles and fifty feet of coal might not be too great. This would amount to 1,400 million tons. The coal is bituminous and probably coking. The coal at the south end of the basin appears slightly harder than toward the north, judging by the analyses of the upper seams. Three analyses of seams in this part of the measures, show the character to change slightly as indicated above.

Locality.	Thickness.	Moisture.	Volatile.	Fixed Carb.	Ash.
Bighorn River	6′ 0″	0.73	22.97	71.45	4.83
S. Brazeau	4′ 0″	0.90	23.92	65.10	10.08
S. Brazeau	14′ 6″	1.20	26.89	61.57	10.34

Résumé.—The Kootanie measures as far as at present known exposed in Alberta (the Crow's Nest area is not here included) has an area of 288 square miles and contains an estimated coal content of 7,930 million tons. This is mostly bituminous in character but a small fraction, 400 millions, can be classed as anthracite:

	Square Miles.	Millions Tons.	
Coleman area	45	2,000	
Blairmore-Frank	50	1,500	
Livingston area	60	1,500	
Moose Mountain	15	250	
Cascade	40	800	
Palliser	6	20	
Costigan	12	60	
Bighorn	60	1,400	
Cascade anthracite		400	
	288	7,530	Bituminous
		400	Anthracite
		7,930	Million Tons

BELLY RIVER COAL FORMATION.

The middle coal horizon is exposed in the foothills in several bands where it is brought up by the general folding and faulting. The coal content is not large, but the quality is very good for domestic fuel. It ranges from lignitic coal to bituminous, but is generally in seams not much over the minimum workable thickness. Under the surface of the plains east of the disturbed foothill region the beds are nearly horizontal and are exposed by the erosion of the deep trough through which the branches of the South Saskatchewan flow. A slight roll in the measures in the eastern border of the province gives an additional area of exposures northwestward.

As the coal seams are in the upper part of the formation there is a certain portion of the county surrounding the portion mapped as Belly River formation that can be included in the coal area as

the seams may be reached by boring. In the northern extension the coal seams, so far as found, appear to be thin. In the area between Medicine Hat and Lethbridge coal seams of about five feet thickness are found over large areas. The seam at Lethbridge is five and a half feet and is mined in several localities near the railroad. Northwest it is divided by a clay parting into two benches, but the quality is good and is classed as a lignitic coal. This means that although in time it breaks down on drying, yet it is almost a true coal. Toward Medicine Hat the quality is not so fair and is there classed with the lignites.

The area over which a workable seam might be found can hardly be estimated, but as the formation is exposed over an area of about 25,000 square miles, one fourth might be assumed as valuable, say, 6,000 square miles. This, with four feet of coal, represents the very large amount of 26,000 million tons of coal. The analyses from the following localities show the decrease in moisture content westward from Medicine Hat:

Locality.	Thickness.	Moisture.	Volatile.	Fixed Carb.	Ash.
Stair No. 6 level	5′ 0″	20.54	33.26	41.15	5.05
10 miles west of Medicine Hat	4′ 0″	16.82	31.90	43.98	7.30
McPhee Mine Sec. T. Tp. 10 R 17, W. of 4th	2′ 7″	11.35	29.98	51.63	7.04
Tabor Mine, Lower bench	3′ 3″	7.21	39.18	46.36	7.22
Lethbridge	5′ 6″	4.73	34.61	50.43	9.89
Stony Reserve, Morley Fo o	6′ 0″	1.26	41.30	48.60	8.84

In the disturbed area of the foothills the formation as a rule contains seams of coal that in many cases are bituminous.

EDMONTON FORMATION.

The third and in point of age the newest formation bearing coal is what was formerly called the Lignitic Tertiary and Laramie. This is a series of brackish water beds at the top of the Cretaceous. They are merely passage beds from the marine Cretaceous to the fresh-water Tertiary above. A few coal seams are found above the limits of the brackish water beds, but the

greater accumulation of carbonaceous material seems to have been formed at about sea level. These rocks are grouped under the name Edmonton formation, a division suggested by J. B. Tyrrell for northern Alberta. The formation is in the form of a trough with gentle dip on the eastern limb, but reappearing in the foothills with steeper slopes. Toward the north the trough broadens and the dips are less pronounced, so that a much larger area is exposed, and in this heavier seams occur. The vicinity of Edmonton is an almost continuous coal field. The coal is lignitic and only in the disturbed areas near the mountains does it approach the character of bituminous coal.

The area over which the formation has been traced is enormous, and in the foothills is estimated at 2,000 square miles. On the prairies there is about 10,800 square miles underlain by the formation which, if as well supplied as near Edmonton, will average a good six feet. The foothill exposures show seams as high as twenty-four feet in thickness and for this an estimate of 11,000 million tons does not seem excessive. This will be of the nature of lignitic coal, while of the lignite 60,000 million tons would be a maximum estimate for the northern and eastern outcrops. A few analyses are inserted to show the range from the best downward in the scale. The foothill areas provide as usual better analyses than the eastern sections.

Locality.	Thickness.	Moisture.	Volatile.	Fixed Carb.	Ash.
Head of Pembina and McLeod rivers	24′ 0″	4 32	33.43	56.49	5.14
Red Deer River 4 miles below Williams Creek	9′ 0″	4.97	36.87	54.05	4.11
Bow River Mine	4′ 6″	4.41	40.32	48 27	7.00
Crowfoot Creek	6′ 0″	11.25	35.59	47.24	5.92
Big seam, Saskatchewan River	24′ 0″	11.88	35.31	47.06	5.08

The estimate of area and coal content for these three formations may be summarized from the above:

	Square Miles.	Millions Tons.
Kootanie formation	288	7,930
Belly River formation	6,000	26,000
Edmonton formation	12,800	71,000

THE GEOLOGICAL OCCURRENCE OF ROCK SALT IN LOUISIANA AND EAST TEXAS.

G. D. HARRIS.

INTRODUCTION.

The five remarkable elevations known as the "Five Islands," or the "Salt Islands" of Louisiana have been frequently described and discussed in geological literature. They are comparatively elevated, island-like areas that rise abruptly above the low marshy country lying nearly at tide-level, and form, as remarked by Lucas,[1] the most conspicuous landmarks for hundreds of miles along the coast of the Gulf of Mexico. Recent exploration has revealed many more of these salt-deposits, most of which do not form topographic islands, but are planed down by erosion to the level of the surrounding country. To these deposits, whether topographically prominent or not, the term *saline* has been applied and this will be used in the present paper. The distribution and number of the salines may be readily seen on the accompanying map (Plate I) opposite page 13.

The origin of these deposits is intimately connected with the stratigraphic and structural features of the region and has been discussed in some detail in a recent report of the Louisiana State Geological Survey.[2] The conclusions reached there are believed to have such direct bearing on the origin of many of the well-known salt deposits of the world as to warrant a brief separate presentation to the readers of ECONOMIC GEOLOGY. In the state report mentioned full details of the Louisiana occurrences are given, with a summary of the principal features of the geological occurrence of the known salt masses of the world. To that report the reader must be referred for the many details quite impossible to present in a brief article like this. The purpose of

[1] *Trans. Amer. Inst. Mng. Eng.*, XXIX., p. 464.
[2] Bulletin No. 7.

PLATE I

LEGEND
SABINE PENINSULA
CITIES
SALINES
OLIGOCENE
FAULT LINES
HYPOTHETICAL FAULT LINES
GULF OF MEXICO
RED RIVER FAULT
BALCONES FAULT LINE
CRETACEOUS
EOCENE
AUSTIN
SHREVEPORT
SABINE
CLAIBORNE
JACKSON
OLIGOCENE
VICKSBURG
ANDERSON
CITY
GRAND SALINE
STERLINGTON
HUMBLE
BARBERS HILL
HOUSTON
GALVESTON
HIGH ISLAND
BRYAN
BIG HILL
DAVIS
BAYTOWN
SOUR LAKE
WINNIE
MAYHEW
CRYSTAL BEACH
BOLIVAR
PENINSULA
ORANGE
BEAUMONT
SOUR LAKE
VINTON
LAKE CHARLES
DEQUINCY
EDGERLY
SULPHUR
CITY
CALCASIEU
LAKE
CAMERON
CREOLE
HACKBERRY
GRAND CHENIER
CAMERON
CREOLE
OIL
LAKE ARTHUR
JENNINGS
WELSH
EDGERLY
DUSON
CROWLEY
RAYNE
MORSE
ABBEVILLE
KAPLAN
GUEYDAN
DELCAMBRE
ERATH
LOUISIANA
MARSH ISLAND
BELLE ISLE
COTTON VALLEY
CARLIN

this paper is to present a brief review of the principal facts which bear upon the genesis of the deposits and the conclusions to which they have led.

The origin of these salines is so intimately connected with the stratigraphic and structural features of the region that in order to appreciate the mode of occurrence of the rock salt, certain general structural and stratigraphic peculiarities must first be clearly understood. These will be therefore briefly reviewed.

STRATIGRAPHY OF THE LOWER MISSISSIPPI SALT REGION.

In the main the stratigraphy of this region is quite simple. The rocks of the area represent Cretaceous, Tertiary and Quaternary sediments. The following table gives the various formations:

TABLE OF FORMATIONS.

QUATERNARY.			
TERTIARY	Miocene.		
	Oligocene	Upper Oligocene.	
		Vicksburg.	
	Eocene	Jackson.	
		Claiborne.	
		Sabine.	
		Midway.	
CRETACEOUS.			

West of the Mississippi these have a gentle dip in a southeasterly direction. Uplifts along fault lines complicate matters somewhat and are of large importance in the present connection.

CRETACEOUS.

Upon the accompanying map, Plate I, the general boundary between the Tertiary and Cretaceous beds is indicated. West of this line the Cretaceous forms the country rock over vast areas. East of it the Cretaceous is found only in isolated outcrops. To the north, near Little Rock, Arkansas, the Cretaceous is overlapped and hidden by Tertiary beds. In Mississippi the Cretaceous-Tertiary border line runs in a north-northwest, south-southeast course, turning easterly across Alabama.

In addition to the larger areas of Cretaceous rocks, upturned beds of this formation outcrop in the immediate vicinity of the salt deposits or "salines" in east Texas and north Louisiana. The surface rocks are here of Tertiary age and the underlying Cretaceous only appears when in the vicinity of the saline. These Cretaceous beds carry many characteristic fossils. These inliers of Cretaceous protrude through the thick Sabine and Clai-

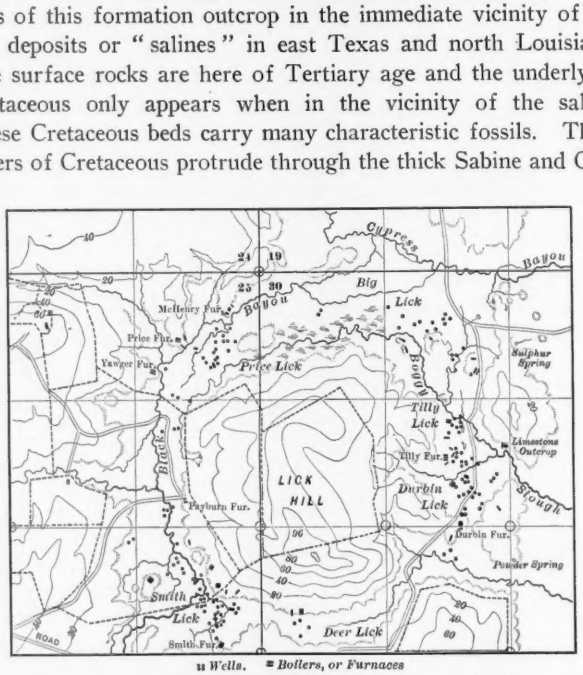

FIG. 2a. Sketch map of Price's Saline, North La. and vicinity, showing typical saline and the circular arrangement of boilers and salt works about its periphery.—*Veatch.*

borne deposits of the Eocene which overlie them and have been thought by some writers to represent antecedent hills of circumdenudation newly exposed by erosion of the Tertiary beds. From evidence which will be presented in this paper, however, it seems more probable that they have reached their present position by being thrust upward through the overlying beds. Detailed evidence for this statement is given on a later page. One or two thousand feet of uplift in an area but a mile or two across is nothing unusual in Louisiana geology. A sketch of one such area showing the characteristic circle of salt works is illustrated

in Fig. 2*a*, p. 14. Many others have been mapped by Veatch[1] and practically all of them are illustrated in the special report to which reference has already been made.[2]

The association of salt and sulphur with these peculiar structural domes is of such frequent occurrence that in several instances beds in the southern part of the state have been referred to the Cretaceous solely on account of their salt and sulphur contents. Such references, without the aid of fossil remains, in a region of vast thicknesses of Tertiary and Quaternary beds seem scarcely justifiable.

It is interesting to note here that the Cretaceous rocks appearing about the peripheries of the northern salines are not the uppermost Cretaceous stages, but rather those at about the horizon of the Nacatoch marls or Anona limestone, *i. e.*, below the Arkadelphia clays that cap the Cretaceous in southwest Arkansas.

EOCENE.

Midway.—In the state report issued for '99 the writers referred to fossiliferous "Midway" outcrops at King's Saline and at Rocky Springs church, between Many and Marthaville. Many wells about Shreveport and in the Caddo Oilfield appear to penetrate the Midway beds between depths of 450 and 600 feet though no Midway fossils have as yet been identified from such wells. Again, about Marthaville there are doubtless local outcrops of uppermost Midway clays still undiscovered. In general, however, the Midway stage rarely appears at the surface in this section of the country.

Sabine Stage.—To the west in Texas and to the north in Arkansas especially, the littoral sands and clays of this stage contain very few animal remains, and are therefore distinguished with great difficulty from the similarly formed Claiborne deposits. In one area, known as the "Sabine Peninsula," a southeastwardly projecting tongue of the Sabine formation, indicated on the map (Plate I), there is an opportunity to study deposits

[1] La. Geol. Rept., 1902, pp. 41–100.
[2] La. Geol. Survey, Bull. 7.

formed a little farther from shore. Fossils are here very abundant and the area was originally defined on paleontologic grounds, but has since been found to be bounded by abnormal dips along the southeastern and eastern margins.

Claiborne Stage.—The beds of this stage outcrop in a narrow strip off the southeast front of Sabine Peninsula and pass with a comparatively high southerly dip beneath Jackson deposits. On either side of the peninsula the Claiborne beds lap back towards the northwest in well-formed embayments, on the west to Brook's saline, on the east to Bistineau. No outliers are known of Claiborne or Sabine Eocene comparable to those of Cretaceous age already described.

Jackson Stage.—As a rule the Jackson Eocene beds outcrop south of the Sabine Peninsula in normal sequence, but to the north, strangely enough, these rocks are absent about the Lower Claiborne area of north Louisiana, though widespread in Arkansas. In Jackson times the Mississippi embayment of the Gulf extended quite probably to Cairo, Ill.

East of Harrisonburg, in the Grand Gulf area, Jackson fossils have been found in abundance in a deep "oil well." In the log of the deep Marksville well, however, no mention is made of fossil remains. At Sour Lake, Texas, Jackson fossils come within less than 1,050 feet of the surface in places, whereas in the test wells, a few miles away, not even upper Tertiary rocks have been recorded for much greater depths. The occurrence of Jackson fossils at about 1,000 feet at Sour Lake is most noteworthy, since a clearly defined Quaternary molluscan fauna occurs in the sands just above the oil at Saratoga at a depth of 950 feet, and a well but perhaps three miles southeast of Sour Lake shows no signs of Tertiary fossils at a depth of 1,900 feet. The Galveston well, the Lake Charles well, and those drilled by Mr. Knapp about Belle Isle, show clearly that 2,000 feet of Quaternary may usually be expected along the Gulf coast.

OLIGOCENE.

Vicksburg Stage.—So far as known the Vicksburg beds do not extend west of the ninety-second meridian. Their last ap-

pearance is just west of the Ouachita, near Rosefield, La. They are unknown in well sections.

Upper Oligocene Deposits.—In central Louisiana these beds have been accumulated in brackish and fresh water; also, perhaps, subaërially. This is likewise true of the deposits at the classical locality, Grand Gulf, Mississippi. In Texas they occasionally show brackish or marine types of molluscan life. Their apparent representatives in the Sour Lake wells at depths from 600 to 850 feet are of purely marine character. Clearly, then, at the close of the Vicksburg age crustal movements took place, producing differential elevation and a shallow zone of accumulation to the southwest and to the southeast from Grand Gulf, Mississippi. Some portions of southeast Louisiana must have been above sea level during part or all of this time. The oölitic lime particles, the gypsiferous, red and green sands, and shales that often accompany the Grand Gulf sandstones, speak clearly of the general climatic conditions of these times.

The extensive loading of these upper Oligocene troughs with sandstone, clay and marlites caused a subsidence throughout their whole extent; hence they are doubtless characterized by a synclinal structure. This means that perhaps the deposits of Eocene age are at a less depth below the surface along the Gulf coast than along the southern edge of the Oligocene area. Certain highly colored clays at Spring Hill, Anse-la-Butte, Spindle Top and near Sour Lake, are believed to be possibly referable to the Oligocene on account of lithologic appearances, but none of the deep wells in the Jennings field, though encountering the *Rangia Johnsoni* Miocene beds at a depth occasionally of but 1,000 feet and continuing in the same for 1,700 feet, show traces of Oligocene deposits.

MIOCENE.

Definite knowledge relating to the buried Miocene beds of the Louisiana and Texas Gulf coast is limited to what has been found in two localities, viz., Galveston (the deep well) and Jennings (Prairie Mamou) oil-field. In the former there is a purely marine molluscan fauna from 2,500 feet downwards as far as

the record goes. In the Jennings oil-field the *Rangia Johnsoni* fauna begins at depths varying from 1,000 to 2,000, according to distance from the center of uplift.

Apparently, southern Louisiana in Miocene times as to-day was characterized by small bays, lakes, channels and shallow bodies of water, teeming with brackish water molluscan species. The clays in the center of the oil-field, coming from a depth far below the Johnsoni fauna, contain *Rangia cuneata* (a living species) in abundance. They duplicate in appearance the muds from the bottom of Atchafalaya Bay or Lake Pontchartrain. The well sections determined by Mr. Knapp about Belle Isle show conclusively how present-day conditions have repeated themselves again and again while 2,000 feet of Quaternary have been depositing.

PLIOCENE.

So far the writer has seen no evidence pointing to the occurrence of Pliocene beds in Louisiana and east Texas. Since so much shifting about of shore lines took place during the Cenozoic era in south Louisiana, and since there is reason for supposing that the continental area was considerably extended in late Tertiary time, the belief is justified that the area of Louisiana and some tracts of land to the south were considerably above sea-level in Pliocene times.

QUATERNARY.

The occurrence of mud or clays of recent appearance from Miocene horizons in the Jennings deep wells has already been mentioned. Similar material, alternating with coarser, *i. e.*, sands and gravel, make up the 2,000 feet of Gulf Coast Quaternary. The coarser "Orange Sand" or "Lafayette" material throughout this great range suggests strong current action, and doubtless occasional differential uplifting during this modern period of geologic history.

STRUCTURAL PECULIARITIES IN THE LOWER MISSISSIPPI REGION.

FAULTS AND FAULT ZONES.

On the west side of the area included in the map (Plate II) is the Balcones fault zone, near the Eocene Cretaceous border, to which reference has been made. To the north is the Red River fault and its probable eastern continuation, the Alabama Landing fault. These faults, the last only excepted, are in well indurated rocks, are well exposed, and hence easily detected. Underlying the Tertiary and Quaternary areas here mapped it seems certain that faults and other structural features exist at many points. The evidence for this belief will be briefly presented.

The "Sabine Peninsula."—Abnormal dips are found along the southeastern margin of this "Peninsula." Along its northeastern flank may be noted a series of uplifts, while Oil City, Steins' and Grand Sabine are very suggestive of fault lines along its southwestern side.

Dome Alignment.—The individual domes commonly show an elliptic plan or an alignment suggestive of common relations to some feature of general deformation. Winnfield and Coochie domes are elliptical in outline and are drawn out in a northeast-southwest direction, corresponding apparently to a line of structural weakness along which they are located. The alignment of domes along the northeastern flank of Sabine Peninsula has already been indicated. Stein's, Brook's and Anderson's in Texas are parallel in direction to the Balcones faults. Big Hill, Damon's, Blue Ridge, Dayton and Davis agree in alignment with what we have already called attention to along the southeastern end of Sabine Peninsula and with the Gulf shore from Tampico to Corpus Christi. High Island—Big Hill—Spindle Top is another remarkably well defined dome line. Others are indicated on the accompanying map.

The northwest-southeast direction of the domes in north Louisiana has often been commented upon, as has been the alignment of the Five Islands. Prairie Mamou dome is on a line

with these islands. Spindle Top, Sour Lake, Batson and Davis are ranged along a parallel line. Other dome lines are apparent on the map.

Oil Pools.—The so-called oil pools platted on the gulf maps of the Hydrographic Bureau agree most remarkably in general alignment with the direction of the Five Islands.

Course of the Lower Mississippi.—By taking a Coast and Geodetic Survey sheet of the mouth of the Mississippi and adjacent regions and observing the sixty-fathom line, it becomes apparent at once that the course of the river, for some distance above Baton Rouge to its mouth, is determined by a syncline, agreeing in alignment perfectly with Bistineau-Winnfield dome line of north Louisiana already mentioned. The prolongation of the Five Island line into the Gulf marks the location of a slight anticline. This feature was first brought to the writers' attention by Mr. I. N. Knapp, who has had charge of extensive oil prospecting in the vicinity of Belle Isle.

Area of Vicksburg Deposition.—The Vicksburg beds seem to have been deposited in a broad V-shaped area whose limbs correspond in direction to the two systems of structural lines described. Vicksburg fossils at the surface or from wells far west of the Ouachita River have yet to be recorded. Deposition of the Grand Gulf Oligocene in the immediate vicinity of the Mississippi seems also to have been controlled by structural conditions, but farther to the southwest it seems to have disregarded them.

Terrestrial Magnetism.—The Sabine Peninsula seems also to produce an effect on declination. The drawing together of the isogonic lines may be observed on the map (Plate II) copied from the Louisiana Survey Report of 1905. Wherever observations have been sufficiently numerous, as about Winnfield, in south-central Louisiana, and about New Orleans, the dependence of abnormalities in terrestrial magnetic forces and structural complications seems well established.[1]

[1] See Rucker & Thorpe, "Magnetic Survey of the British Isles," *Philos. Trans.*, Series A, Vol. 188, 1896, pp. 651–658.

DOMES.

It is evident from what has been stated above that in the main the stratigraphy of the lower Mississippi region is quite simple. There are, however, certain most remarkable and surprisingly local uplifts in the form of domes.

In our use of the word "dome" we do not imply a local topographic feature, but rather a structural feature; one characterized by qua-qua-versal dips. The newer domes along the gulf border are really domes topographically as well as structurally. The older domes to the north are apt to be topographically plane, or even concave.

Origin.—These domes have been looked upon as old Cretaceous peaks, left by circumdenudation through early Tertiary times, and finally surrounded by later Tertiary sediments, appearing now like monadnocks in a continental ice-sheet. Gas pressure has been appealed to also as an important factor in their genesis. Water, under tremendous pressure, has also been considered the real lifting force. Deep-seated igneous plugs have been called upon to lift, Atlas-like, thousands or millions of cubic yards of earth upon their backs while "floating upwards"!

By inspecting the accompanying map (Plate I) the reader will doubtless convince himself that if all the faults in the beds beneath the Tertiary were located, domes would be found to occur mainly at the crossing of such fault lines. The crossing of these lines naturally determines a point of weakness that would be utilized by any gaseous or liquid substance under pressure from below seeking relief upwards. The existence of such substances under such conditions is well known; in fact, the dip of the strata in the Mississippi Embayment area—southeast-west of the Mississippi and southwest-east of it—suggests artesian conditions along the Gulf coast. There is no reason why waters entering the pervious layers far up country should not go down to greater and greater depths as the latitude of the Gulf border is approached. Such waters might reach considerable depths, be raised accordingly to a high temperature and take in solution many salts, especially chloride of sodium. Ascending under

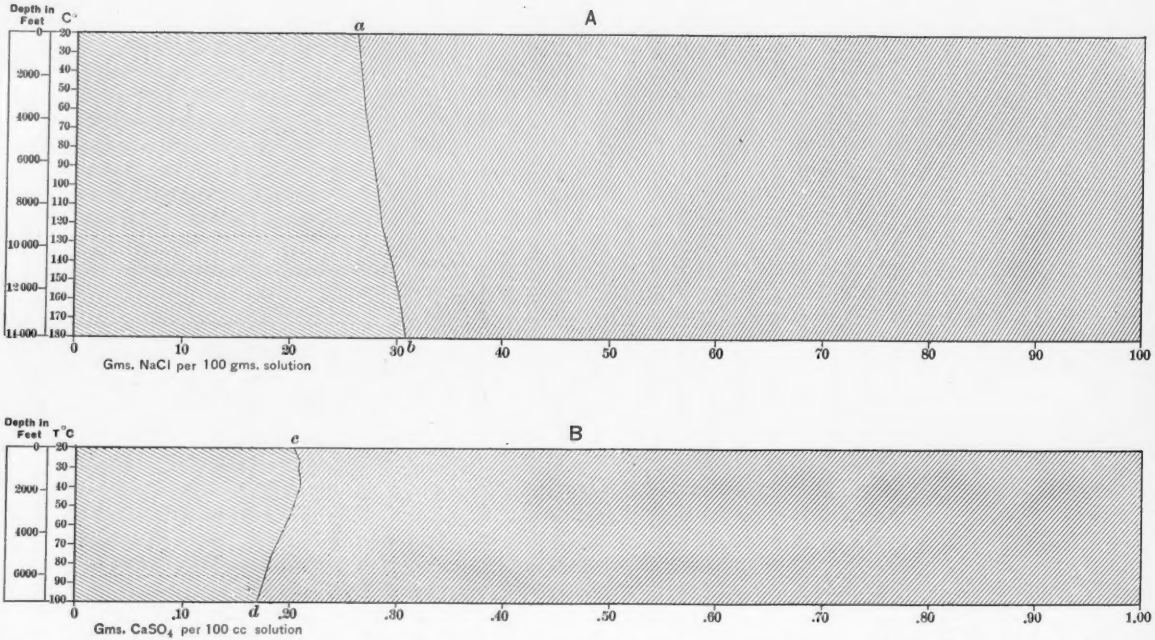

FIG. 3. Diagram showing *A*, amount of NaCl held in saturated solution at various temperatures from 180°–20° C., also at about what depths such temperatures would be normally encountered; *B*, amount of $CaSO_4$ held in solution under circumstances as in *A*. Scale of *B* equals 100 times *A*.

hydrostatic pressure at the above-mentioned points of weakness and cooling normally at the rate of 1° C. for every 90 feet of ascent, a point would be reached where the solution, if saturated at a high temperature, could no longer retain all its salts. Precipitation would begin, rapidly at first, as indicated by Fig. 3, *A* and *B*, but decreasing slowly as cooler surface temperatures are reached.

With precipitation of salt would naturally go crystallization. The power exerted by growing crystals (in general) may be assumed to be of the same order of magnitude as the crushing strength of the crystals themselves.[1] We have subjected a four-inch cube to a pressure of 50,000 lbs. without even cracking it. Tournaire crushed cubic centimeters of rock salt with pressures of from 332 to 461 kilograms. If the specific gravity of Quaternary clays and sands be taken as 2.4, then growing salt crystals could lift up 3,000, 4,000 or even 5,000 feet of such incoherent strata.

Fig. 4, Nos. 1, 2, 5 and 6, show hypothetically the earlier stages of dome-growth. A pervious layer is more or less fractured by faulting below, see Fig. 4, No. 1, and, after salt has been precipitated and crystallized, there is a slight arching at the surface and a condensing of the incoherent surrounding beds as indicated in Fig. 4, No. 2. At first the salt core would be a slender, pencil-like cone. By rapid growth at the base the the apical angle would become greater and greater. The exact shape of the base of the cone would depend on many things, among which would be the comparative thermal conductivity of the salt core and the surrounding and subjacent materials. Crystals formed on the base of the cone would give the whole mass an upward movement like a pelelith. The apex of the cone would soon be above the isogeotherms where salt deposition is possible; and. being of very limited lateral dimensions, it would soon be dissolved by circulating underground fresh waters. However, the compacting slickensiding of the deposits about the lower main part of the cone would tend to debar the close approach of fresh waters, and yet leave a suture line for the ascension of brines. So

[1] Day and Becker, *Wash. Acad. Sci. Proc.*, Vol. 7, 288, 1905.

FIG. 3. Diagram showing *A*, amount of NaCl held in saturated solution at various temperatures from 180°–20° C., also at about what depths such temperatures would be normally encountered; *B*, amount of $CaSO_4$ held in solution under circumstances as in *A*. Scale of *B* equals 100 times *A*.

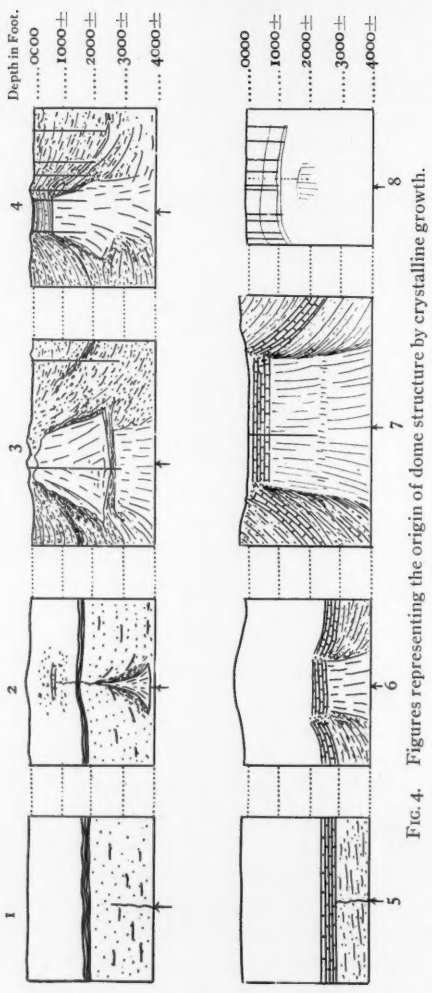

FIG. 4. Figures representing the origin of dome structure by crystalline growth.

long as the supply of salt water lasted, the salt core would continue to grow and rise. But movements along the various fault lines already depicted might at any time shut off the supply of brine. Other solutions might be forced up through the channels formerly conducting salt water. We note in the domes, next in importance to rock salt, gypsum, limestone, dolomite, indurated calcareous and silicious lenses of varying shapes and dimensions. Sulphur, even, alternates with gypsum layers. Oil and gas are found wherever some dome-forming material has produced the proper structure to concentrate and retain such substances. In an ordinary salt cone there should be growth not only on the bottom but also on the sides. The ascending saline solutions would naturally vary somewhat as slight movements took place

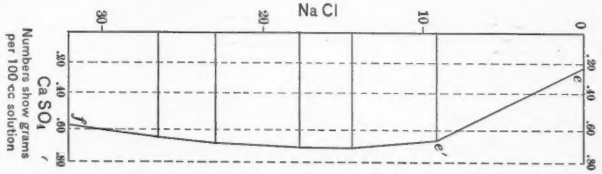

FIG. 5. Showing solubility of $CaSO_4$ in varying solutions of NaCl.

in the deep-lying beds below and northward from any dome-forming area. These variations would be apparent in the salt as nearly vertical streaks or layers when the mass is exposed in the huge chambers of salt mines. These streaks, then, may be regarded as layers of exogenous growth, rather than ordinary bedding planes highly inclined.

It is interesting to note that, under ordinary stable conditions, calcium sulphate would be a cool, near-surface, deposit, as indicated in Fig. 3, *B*, or as in Fig. 4, No. 8. For Fig. 3, *B*, shows that up to a certain point, about 40° C., cooling increases the power of water to hold this substance in solution; hence we would expect, if no crustal movements have taken place, to find secondary deposits of gypsum within less than 2,000 feet of the surface. In this case, however, we have been considering a solution of $CaSO_4$ in fresh water. Fig. 5 shows that with the decrease of salinity, especially between 14 per cent. and 0 per cent., goes

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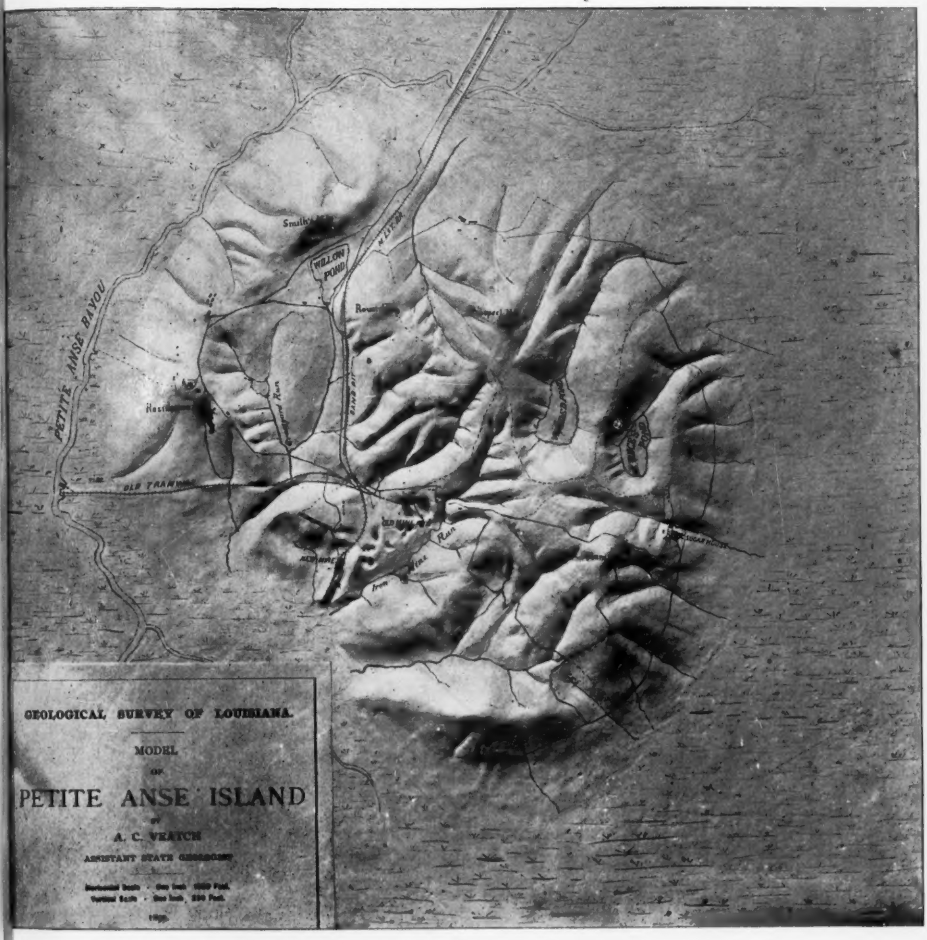
a like decrease in power to hold $CaSO_4$, unless there are irregularities in the curve between *e'* and *e*. Diluting the solution with one containing $CaSO_4$ would doubtless cause precipitation of this salt near the surface. Diminution of heat as the surface is approached produces a tendency in the same direction as already stated. Perhaps herein lies the explanation of the occurrence normally in Louisiana and Texas, as noted by Fenneman[1] of $CaSO_4$ above NaCl.

Crustal movements affecting the area where salt domes are forming, changing to any considerable extent the surface of the land, must have a marked effect on the shape of the salt mass. Sinking of the land (and salt mass) would raise the isogeotherms (relative to the salt mass already formed) and perhaps cause a re-solution of the base of the mass and a deposition of the same material higher up. A considerable rise in the dome-forming district might cause a salt core to appear eventually at the surface. Through denudation its growth would cease, while below another mass might start forming. With all such movements supplies of one solution might be cut off, while those of another might appear; hence the complexity of structure often found in Louisiana and East Texas domes. The writers regard Petite Anse (Plate II, also Fig. 4, No. 3) as a case where crustal movements were upwards, positive, causing the cone to be truncated by erosion, though mainly preserved by the compacted layers about its sides, from the attack of the fresh undergoing waters so prevalent in all this part of the State. A second salt mass below, as indicated in the figure, has been reached by the drill. A mile away a well was put down to a depth equal to the one in the salt mass without even obtaining salt water. This fact, it seems to us, is quite sufficient to prove the impenetrability of the compressed layers about the salt mass so far as the subterranean, surrounding fresh waters are concerned. The shape of the lower salt mass is naturally purely hypothetical. Plate II shows the present appearance of a very recent salt dome. Fig. 4, No. 4, shows the main structural features of Anse la Butte. Two wells penetrate the truncated cone from 600 to 1,800 feet,

[1] Bull. U. S. G. S., No. 282, p. 18.



THIS IS ABOUT ONE-HALF THE DIMENSIONS OF THE MODEL

(From La. Geol. Sur. Rept. 1899.)

others enter the cone lower down. One penetrates a secondary salt mass before the porous oil stratum is reached. We look upon this secondary mass as having been formed from a saturated solution of waters above the truncated cone while seeking a lower level. This solution would certainly meet with a very heavy gas pressure and hence the probabilities are that salt would be precipitated. Crystallization would begin at any rate. Several secondary domes are commenced about the periphery of the central swamp, as indicated in No. 4. It is evident that oil wells but a few hundred yards from the salt mass may be very successful; others, but a little farther away, will meet only with brine, if the driller is persistent enough to go down to the oil- and brine-bearing stratum. Oil and salt water here show temperatures of 130° and 132° F. Gas bubbles continuously about the edges of the flat swamp area, precisely where it would be expected in view of the relations of salt and rock masses as shown by well sections.

The hot waters at Anse La Butte and other localities cause great uncertainty as to the depth below the surface at which salt cones have been formed and are now forming. If through a crevice a large amount of hot brine is forced upwards it may heat all surrounding beds, so as to raise the temperature sufficiently to cause the salt to be precipitated and crystallized near the surface. A salt mass so commenced could grow downwards only by (1) the appearance of a more highly saturated solution, or (2) the elevation of the area where the salt mass is forming.

A somewhat modified type of dome structure occurs where there is a comparatively thick, rigid layer above the salt-forming locus (see Fig. 4, Nos. 5 to 8). Nos. 5 and 6 are purely hypothetical cross-sections. No. 7 is a section of Drake's saline in northern Louisiana. In the midst of Eocene sands and clays this saline, approximately a mile across, occurs with brine springs about its periphery. In the center salt was encountered at 900 feet and gypsum at 2,300 feet, the very bottom of the test well. An old test well, reported from the right-hand side of the section (No. 7), is said to have passed through 1,100 feet of limestone. Oil and gas are reported from the margin of this saline. Calcareous sandstones, evidently Cretaceous like those

in adjoining salines, appear tilted up at a high angle at a locality corresponding to the left margin of the salt mass (Fig. 4, No. 7).

At the Spindle Top dome, so far as we are aware, only two wells have passed the porous "oil rock" and gypsum and penetrated the salt core. These wells, however, suffice to show the real core of this dome. Here we see calcareous matter forming a laccolith, so to speak, which the salt core, in lifting bodily, did not break, for it was evidently not a continuous sheet like the Cretaceous limestones in No. 7. A slight central arching took place which, owing to the impervious clay layers above, produced an excellent oil-gathering structure.

Limited Dimensions.—The extremely limited horizontal extent of the salt masses of this region has frequently been commented upon. In fact it forms an insurmountable obstacle to those who would account for them as portions of old, uplifted, salt-bearing strata. They are not parts of dissected ridges but true domes. Again, of all substances forming rocky layers in the earth's crust, salt would be first to be removed by erosion, rather than last, resisting such action and forming, as we have said, "monadnocks" in the seas of later sedimentation. If, however, we assume that the salt masses have grown largely by additions from below, then, since the specific gravity of salt is less than that of the surrounding sand and clay layers, relief from the stress of the growing crystals would take place mainly along the line of the salt mass. Limited horizontal and great vertical dimensions would therefore naturally be expected.

Origin of Saline Solutions.—It is quite safe to say that the saline solutions spoken of above originate in the Mesozoic or Paleozoic beds beneath the Gulf coast Tertiaries, since the salt has not come from concentrating and sinking salt lakes. Everything shows the movement of the salt masses or growth has been upwards, not downwards. The simplest mechanic or layman can quickly demonstrate to the satisfaction of all whether a boiler has exploded from forces within or has been crushed by extraneous forces. The case is similar here. A ring of Cretaceous rocks peeping out around the edges of the northern salines surrounded outside by thick Eocene deposits, bespeaks a local uplift,

FIG. 6.

FIG. 7.

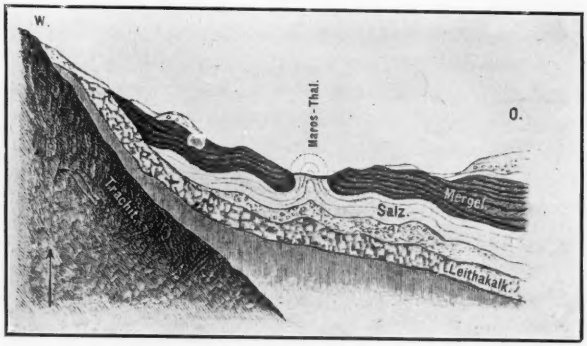


FIG. 6. Section of Maros Valley, Hungary. (After Lamprecht in Fürer's Salzbergbau.)

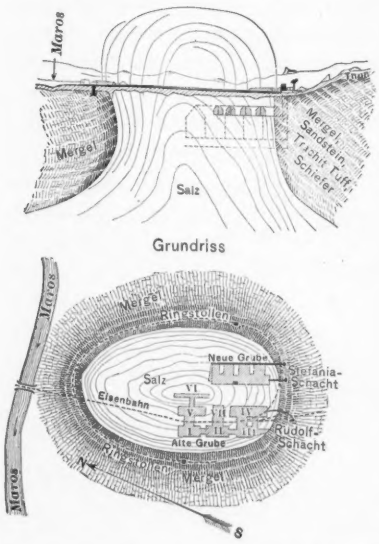


FIG. 7. Plan and cross-section of salt mine in Maros Valley, Hungary. (After Lamprecht, *loc. cit.*)

not a down-throw. Eocene at Sour Lake at a depth of 1,000, Miocene at Jennings at 1,000 feet, both in a region of at least 1,500 feet of Quaternary sedimentation mean local uplifts. The well sections at Spindle Top, Anse La Butte, Belle Isle and many other localities speak clearly for extraordinary local uplifts.

The Balcones and the Red River faults are to be seen at the surface. The series of faults parallel to these are, we believe, shown to exist by the facts presented in the earlier part of this paper. At the intersection of these lines weak spots are produced, admitting the upward passage of fluids or gas under pressure from below. The very alignment of the domes indicates faults in the deep indurated rocks of Mesozoic or Paleozoic age. There are no indications that salt-pan conditions prevailed in any Tertiary epoch, except perhaps locally in the upper Oligocene, and many of the salt masses in the northern "salines" are below layers of Cretaceous rocks. We feel, therefore, quite safe in saying that the primal, salt-pan-formed salt layers from which the Louisiana and east Texas domes are formed in a secondary manner are probably early Mesozoic or late Paleozoic.

DOMES IN OTHER COUNTRIES.

We can scarcely expect to find in the world geological conditions that will duplicate those already described in the Louisiana-Texas area. Again, to draw conclusions regarding very difficult stratigraphic points from literature alone would be unprofitable and probably unfortunate. Yet the writers cannot help feeling that all is not well with the ordinary salt-pan theory in accounting for the 4,900 feet of pure rock salt in the Sperenberg well near Berlin. In Fürer's Salzbergbau und Salinenkunde we note in Lamprecht's cross-section (ideal?) of the Maros Valley, Fig. 6, how there happens to be a fold at the right place to bring the salt near the surface. But the section and larger scale and ground plan of the mines and salt crop (Fig. 7), seem to have a circular form, quite different in fact from what might have been expected from Fig. 6.

However, it is evident from descriptions of this and other

Hungarian localities that the Tertiaries contain salt beds laid down in the usual salt-pan manner. Such layers are now but a few hundred feet, or a few thousand feet at most, beneath the surface. Volcanic activities have here left unmistakable signs of their former prevalence. Orogenic movements have been numerous. Solution and re-deposition[1] of salt on a somewhat extended scale is what one might expect here. In fact (Capt.) Lucas, of Washington, D. C., who recently visited that part of the world, informs us that the salt masses observed by him in mines had every appearance of a secondary origin.

The structure of Rhang-el-Melah, Algeria, appears to indicate what one might expect in Louisiana if the climate were arid instead of humid. M. Ville, ingenieur des mines,[2] in 1885 carefully studied this locality and made the plans and sections herewith presented as Fig. 8.

This hill of rock salt (Rhang-el-Melah) is on the southern border of an alluvial basin, on the caravan road, 13 miles northwest of Jelfa. The basin is 70 miles long in an east-west direction and 15 miles wide north and south. It contains two salt lakes (Zahrez), one to the east and one to the west of the north-south caravan road. These lakes are fairly fresh in winter but become extremely saline, precipitating various salts, in summer. Along their southern margins especially fresh-water springs arise. The lakes are fed mainly by saline streams from the west and south. One, L'oued Melah, passes by the salt hill and is very saline. The general dip of the rocks (Cretaceous and Middle Tertiary) is to the northwest, but in the immediate vicinity of the salt hill the strata are tilted as by a volcanic eruption. Ville says: "Tous ces faits donnent lieu de penser que le gîte du rocher de sel est le resultat d'une éruption boueuse et saline que s'est opérée à travers les assises superposées des terrains crétacés inférieurs et tertiares moyens." The salt mass is not stratified, though it shows a slightly banded appearance. Associated, unstratified clay and gypseous matter shows a more

[1] See Fürer, p. 261.

[2] "Notice Geologique," *Annales des Mines*, 5th Ser., Vol. 15, 1859, pp. 351–410, Pl. III.

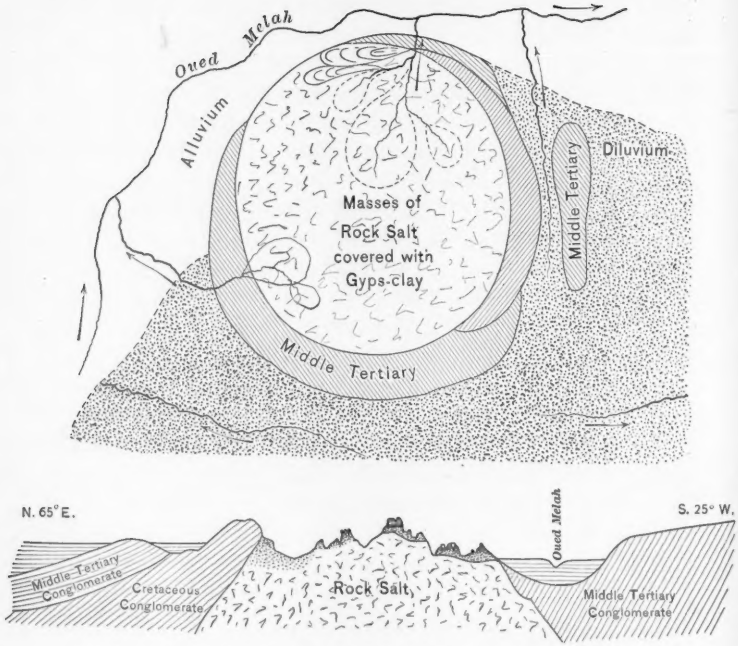


FIG. 8. Map and cross-section of Rhang-el-Melah, Algeria. (After M. Ville.)

marked coloring in red, blue and green than has been recorded in similar Louisiana material. Hardening, or binding together of incoherent matter by silicious paste seems to have been more prevalent here than at the surface in Louisiana, though silicious lenses have often been encountered in wells. This salt dome is one fourth mile in diameter at the surface, but the rock salt is, as indicated by Fig. 8 (above) largely covered. Four or five saline springs occur in the dome, and the oval depressions they have dissolved away (for their waters are not saturated with salt) are indicated by broken dotted lines in Fig. 8 (above). Twenty-one miles southwest of Rhang-el-Melah is a second dome, Aïn-hadjera, two thirds of a mile in diameter, showing less rock salt

at the surface, but duplicating closely the structural features of Rhang-el-Melah.

Along the southern margin of the lakes above mentioned are various " dunes " described by Ville that seem to the writers at a distance suspiciously like salt domes. At any rate here on the northern foothills of mountainous masses with northward-dipping bedding planes, it is no wonder that if the Mesozoic (often salt-bearing) beds of the Sahara are traversed by warm or hot waters, salt domes should result.

FINAL REMARKS.

So far as the writers can judge, the comparatively thin but widely extended salt deposits of the world, such as the Silurian deposits of the New York-Ontario area, are the result of salt-pan evaporation. Salt, however, is readily dissolved by water at ordinary temperatures. Cases where such brines have been evaporated and salt precipitated may be observed in nearly every part of the world. If, as in Hungary, the bed formed in the regular salt-pan way, near enough to the surface to be mined, is folded, faulted and traversed by thermal waters from volcanic vents, it may often require care and patience to distinguish between primary and secondary deposits. If, however, the salt-pan salt is at a very great depth yet subjected to the dissolving power of artesian waters, such waters necessarily being hot at the depths postulated, then the resulting solutions, if saturated at such high temperatures, are obliged to part with their salts as the surface is approached. Growing crystalline masses result. Dome structure follows.

Finally, the reader's attention is called to the method employed by the writer to ascertain the rate of growth of domes. Near one of these, Grande Côte, has been established an automatic tide-gauge in coöperation with the U. S. Coast and Geodetic Survey. Three years' readings have already been obtained, the zero of the gauge has been connected with three bench marks on the dome; the latter has been connected with precise level lines, and finally, through coöperation with the U. S. Geological Sur-

vey, these have been connected with a line of primary levels along the Southern Pacific Railway throughout southwest Louisiana. Differential elevations will doubtless soon be determined, while the general elevation or depression of the coast may be ascertained by a series of tide-gauge readings perhaps twenty-five or fifty years hence.

A PHASE OF GROUND WATER PROBLEMS IN THE WEST.[1]

W. C. MENDENHALL.

In the arid west water is truly a mineral resource, and as the values of useful substances depend not merely upon the degree of usefulness, but upon the scarcity, it follows that in the dryer sections this most widely distributed of minerals comes to have a definite and often high market value. This fact may come home with a shock to the eastern traveller, who, entering a western mining camp for the first time, is forced to pay five or six dollars a barrel for all the water he uses.

When climatic and soil conditions are in the highest degree favorable for agricultural development, but the rainfall is so limited that the agricultural possibilities must remain merely potential until water is artificially applied, the best engineering and legal talent in a community is often absorbed in the solution of problems of water supply. It is in the western communities where these conditions prevail that the phrase has been coined "Water is king." It expresses in compact form the attitude of the desert dweller and of the irrigationist. It is the idea that underlies the annual irrigation congresses and that compelled the reclamation law. Aridity is the king's evil of the western world. By his touch it is cured. The cure is complete where the remedy can be applied, but the king is not omnipresent. Great tracts are hopeless, and under any conditions which we can now foresee will remain hopeless.

Where communities have an unlimited future with abundant water and cease to exist without it; where irrigated lands sell for two thousand dollars per acre, and adjacent and precisely similar unwatered lands for but fifty dollars per acre; where the growth of cities is checked by a limited supply, as by a wall,

[1] Published by permission of the director, U. S. Geological Survey.

and to escape the limitation they may be compelled to go, as Los Angeles has just gone, 250 miles across mountain ranges and through deserts for an additional supply, exhausting its bonding capacity and postponing other hoped-for improvements in the act; where, for irrigation purposes, water is pumped to heights of more than 500 feet, as at Riverside and in the San Joaquin Valley; where annual water charges of as much as $25 per acre per year are paid; where no suits at law are so usual or so bitterly contested as those over the ownership of water; in regions such as these the student of problems of water supply is confronted by economic conditions wholly unlike and much more intense than those that exist in humid areas, where perhaps the most acute problems are connected with the disposal of excess or the maintenance of a safe standard of purity.

The intensity of the need of the climatically favored arid or semiarid sections, has resulted in intense development and great ingenuity is displayed in the full utilization of available water for power and irrigation purposes. The Santa Ana River in southern California may be used to illustrate this condition. A part of the water of this river is stored in a reservoir in the San Bernardino Mountains, and the flow of the stream thereby regulated. After the stored water is released from the reservoir, it is diverted through a power plant and electric power is generated. Below this it is all distributed and used for municipal and irrigation purposes about Redlands and Highlands. The waters that return from the irrigation are recovered in the San Bernardino Valley from springs and flowing wells, and by the use of pumping plants, a portion of the power developed higher up on the stream being utilized for the latter purpose. This recovered water is used for irrigation about San Bernardino and Riverside, a part of it reappears in the river above Riverside Narrows where it is again taken out into a power ditch whose waters are returned to the river above Corona. A few miles below in the lower canyon it is picked up by canals and distributed to the orange and deciduous groves about Anaheim and Santa Ana. The portion of it that returns here, by irrigation, to the ground water, is once more recovered by the many pumping plants and flowing wells

west of Santa Ana in the lower coastal plain. A single drop of water in its progress from the mountains to the sea, a distance of only 100 miles, may thus be used as many as eight times for power and irrigation.

The study of ground water supplies in a region where these conditions prevail is a combined engineering and geologic problem that may have as intimate a relation to the life of the communities affected, as does a study of the ore deposits of Cripple Creek and Leadville to the future of those cities. Such a study must be conducted with the same care that is applied to any other economic problem in order that conclusions, which may effect the whole future policy of the district toward growth and settlement, may be based on the best data obtainable and may be wholly reliable. These are conditions that prevail in many of the arid and semiarid parts of the west, the conditions in southern California. selected in this paper as an example, differing from those of other communities only in this—that the relatively dense population there has centered attention on all the water resources, and has resulted in a refined development that will not be exhibited in more sparsely settled regions for many years to come.

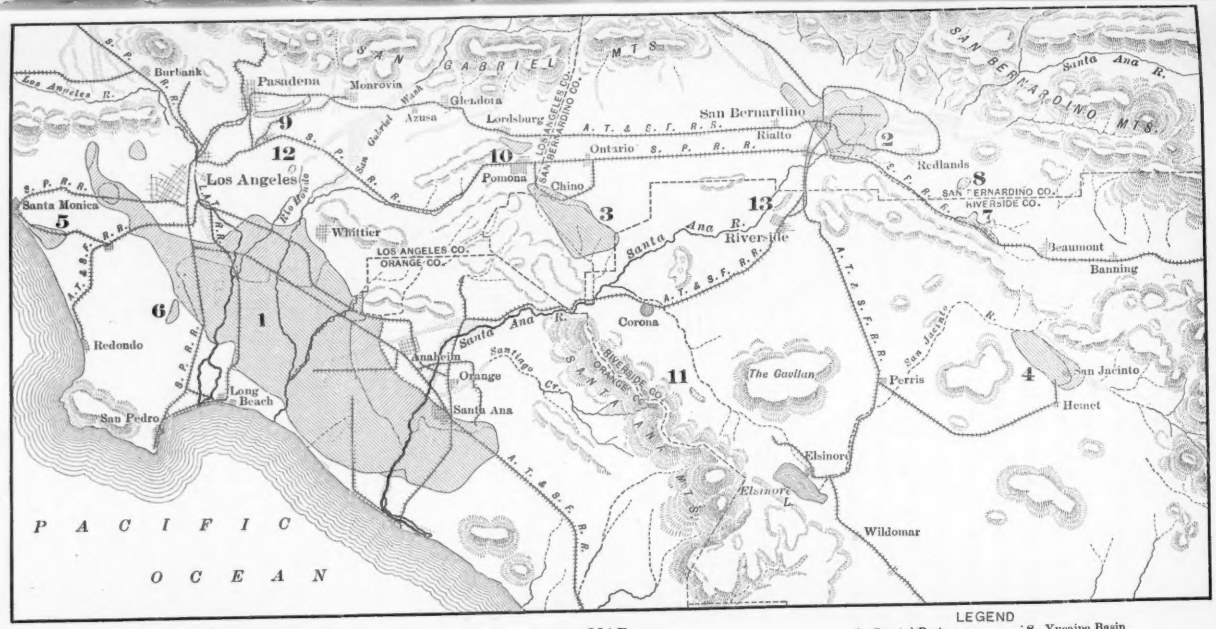
The valley of southern California is the best known part of the state with the exception of the City and County of San Francisco. It lies south of the San Gabriel and San Bernardino mountains, and opens westward to the Pacific without intervening barriers. Los Angeles, Pasadena, Redlands and Riverside, are among its towns that are most familiar to tourists. It has a population of about 500,000, and an irrigated acreage of only about 250,000 where perhaps 750,000 acres are irrigable if water were available. Physiographically it is a complex lowland in that it consists of a number of irregular constructional valleys—sunken crustal blocks—incompletely separated by equally irregular ridges. The surfaces of the sunken blocks are in many cases well below sea level, and the depressions above them have been filled by alluvium derived from the adjacent mountain areas. The ground waters that are used are the waters that saturate this alluvium. The problems are those of their occurrence and distribution, accessibility, recovery, average accessions and the effects upon them

of the various types of development. There are limited areas of folded sediments in the coast ranges near the Pacific, which carry available waters where structures are favorable, but the quality of these is so generally poor that they are not classed among the important resources.

As a preliminary step in the study of the ground waters, statistical data were gathered on more than 10,000 wells, of which nearly 3,000 were flowing and about one half that number were equipped with pumping plants of various types. It was estimated from these data, that about $5,000,000 are invested in wells and equipment, and that the average annual product is equivalent to nearly 500 second feet continuous flow. Four major flowing well areas were mapped in this preliminary work, and nine smaller areas in which flowing water is or has been available, were outlined. In addition to this the usual hydrographic contours were prepared showing the depth to ground water in each of the important districts, and purity data were also secured, although the quality of the waters is generally sufficiently high, so that this remains a rather unimportant issue.

The original combined area of the artesian lands was, as nearly as could be determined, 375 square miles. In 1904 when our studies began to yield definite results, this area had shrunken one third to 250 square miles and other accordant phenomena were not wanting; *e. g.*, the yields of flowing wells, particularly shallow wells, had decreased generally, and in some of the few localities where such phenomena had been observed, there had been a varying decline in ground water levels. It so happened that 1904 was the end of a decade of low rainfall, following several years of unusually heavy rainfall. It was also true that during this period rapid development of the under ground waters had taken place, the limit of use of surface waters having been reached and indeed, in some notable cases, surpassed during the preceding decade of heavy precipitation.

The southern California basins, filled with loose unconsolidated sands and gravels, respond with exceptional promptness to excessive draughts on the one hand or to abundant rainfall on the other. These basins are not independent of local rainfall.


Burbank
Pasadena
Monrovia
Glendora
Azusa
Lordsburg
San Bernardino
Rialto
Ontario
Pomona
Chino
Redlands
Los Angeles
Santa Monica
Whittier
Riverside
Beaumont
Banning
Redondo
Anaheim
Orange
Santa Ana
Corona
Long Beach
San Pedro
The Gavilan
Perris
San Jacinto
Hemet
Elsinore
Wildomar
PACIFIC
OCEAN
LOS ANGELES CO.
ORANGE CO.
SAN BERNARDINO CO.
RIVERSIDE CO.
SAN GABRIEL MTS.
SAN BERNARDINO MTS.
SANTA ANA MTS.
Los Angeles R.
Santa Ana R.
San Gabriel R.
Rio Hondo
Santiago Cr.
San Jacinto R.
Elsinore L.
A. T. & S. F. R. R.
S. P. R. R.
A. T. & S. F. & S. P. R. R.
S. P. & San Gabriel Riv. R. R.
A. T. & S. F. & S. P. R. R.
L. A. R. R.
A. T. & S. F. R. R.
S. P. R. R.
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The recharge of the ground water reservoirs, the restoration of the waters withdrawn by wells, is accomplished by the absorption of the runoff from the bordering mountains, as it crosses the open sands and gravels of the alluvial fans and the effects of a heavy discharge are observable at once in the immediate vicinity of the flood channels and at successively later periods, of course, at points more and more remote from the washes, but in the smaller basins, and in the more important parts of the larger basins, the effect of a winter of heavy rainfall is observable before the end of the succeeding dry period.

It became evident as soon as the larger aspects of the problem were grasped that the practical question for determination, if our work was to be of value to the southern Californian communities, was the question of the relation of the withdrawals of ground water by artificial means to the recharge from precipitation and runoff. If water is withdrawn more rapidly than it is restored, principal as well as interest is expended, and the result must be disastrous in the end. On the other hand, in order that the highest possible use may be made of the under ground waters as a resource, the withdrawals should keep pace with the annual recharge, so that there may be no waste. The problem thus stated seems simple, but, in reality, its solution is difficult. In the first place, we are dealing with averages correctly determinable only after a long series of observations. The under ground basins are storage reservoirs, one of whose most important functions is to tide the dependent communities over dry years, when the surface runoff is at a minimum. Practically no surface system in the district is without subsidiary pumping plants and artesian wells, used only when necessary. During a succession of dry years, nearly all of the irrigating water may come from such sources, while during wet years, when an abundance of surface water is available, many of the wells are not in use at all. There is thus much irregularity in the withdrawals, these being more severe during the periods when recharge is least effective and less severe during the periods when recharge is most effective. And this is a proper use of the ground waters, but it greatly complicates the problem of determining the relation of the aver-

age withdrawal to the average recharge, and hence the maximum safe use.

In general terms, neither of these elements is capable of accurate direct determination. Total recharge is obviously not determinable. It takes place most effectively along the stream channels which are dry except during the rainy season and for a short period thereafter and at certain stages of a stream the amount of water absorbed through the stream bed is measurable and has been measured, but during periods of great flood when much water must percolate through the sandy bottoms to join the ground waters, accurate measurements are out of the question. Furthermore, at such times myriads of rills all about the borders of the basin are contributing a quota wherever they flow across porous material, and during storms with heavy direct precipitation all over the basin, absorption takes place over its entire surface at an unknown rate; and an unknown proportion of this absorbed water is returned to the atmosphere during succeeding days of sunshine by the processes of capillarity and evaporation.

The measurement of recovered waters is not impossible in some of the basins at least, and has actually been accomplished for the San Bernardino Valley, where, during eight or nine years past, the total developed waters and the total waters that rise naturally in springs have been measured twice annually. The total water from both these sources, all of which is used for domestic purposes or for irrigation, has increased slowly, although irregularly, to keep pace with the increasing population of the dependent communities, but the most striking fact brought out by the measurements is the general increase in the amount of developed water, accompanying an equally marked general decrease in the natural waters; that is to say, the flow of springs has lessened markedly as the yield of wells has increased.

Taking from the tables the low water measurements during the first and last years for which figures are available we have the following results:

	Natural Water Sec. Feet.	Developed Water Sec. Feet.	Total Sec. Feet.
September, 1898	78.31	68.38	144.69
September, 1906	46.47	112.26	158.73

Detailed measurements have not been made for other of the many basins that together constitute the valley of southern California, but there is no doubt that were they to be had they would indicate about the same condition that exists in the San Bernardino basin.

Had this condition of gradually decreasing natural waters, with gradually increasing developed waters arisen during periods of average rainfall and therefore of average annual restoration of ground waters, the conclusion would be simple and direct to the effect that there is serious overuse and serious depletion of the stored waters. But, in reality during the first three years of this period there occurred the lowest rainfall for a single year,

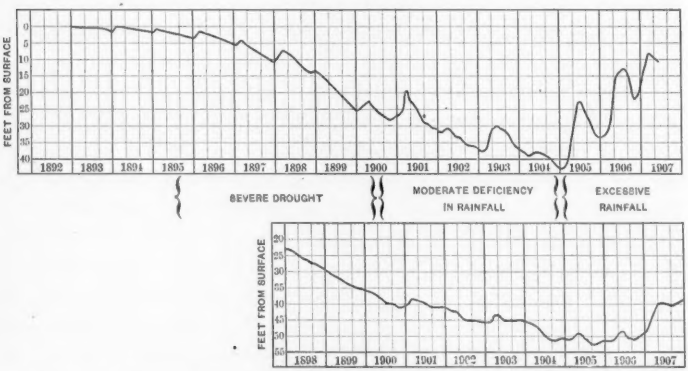


FIG. 126. Generalized Profiles Showing Variation in Water Levels in Two Southern California Wells, the upper near a stream channel, the lower remote from one. Note the more pronounced general and annual fluctuations in the first, and the lag in general recovery in the last.

the lowest rainfall for two consecutive years, and the lowest rainfall for a three-year period that are of record in that section of the state, the severest and longest drought known. This drought was followed by a four-year period of slightly less than average rainfall and that in turn by three years in each of which there was precipitation in excess of the average by about 25 per cent.

The fluctuations of the saturation level were not uniform dur-

ing these years; they were not even always of the same sign in different basins or in different parts of the same basin. Water levels declined almost universally during the drought, but at widely different rates. They declined generally during the four-year period of nearly average rainfall following the drought, although there were exceptions to this rule. They rose generally during the three-year wet period following the period of average rainfall although there were exceptions to this rule also. Most rapid declines during the dry period were near stream channels where drainage was free and near pumping plants where withdrawals were greatest. The recoveries were most prompt during the later period near stream channels and at points remote from centers of development, and lagged or did not occur at all in regions remote from points of recharge but near centers of development.

Just as it has taken time for the withdrawals from a given locality to affect remote localities, so the prompt restoration in the vicinity of flood channels is not necessarily accompanied by an immediate, corresponding recovery in distant parts of the same basin. That is to say, the general upward movement of the saturation level, due to a series of wet winters, may be a year or two later in beginning, in situations remote from lines of recharge, than in the immediate vicinity of these lines. Superimposed upon these broad undulations as irregularities, are the comparatively sharp, wet and dry season waves with a yearly period. These latter are conspicuous and, if observations are limited to one or two years, they only will be detected. Superimposed upon these, in turn, are the minor waves of normal daily variation due to temperature or barometric changes, or of abnormal irregular variation due to the starting and stopping of pumps or the opening and closing of flowing wells. Of this three-fold or four-fold series of fluctuations, the daily and the annual are unimportant elements in the determination of the vital question of reasonable use of the ground waters. It is the general tendency upward or downward of the slow waves of long period, corresponding to periods of drought and of heavy rainfall, that

determines whether ground waters are overused or only properly used.

Despite the universal utilization of ground waters for city supplies and for irrigation, few individuals or organizations foresaw the need of constant records of changes of level until the alarming decline culminating at the end of 1904 compelled their attention. Several companies began making measurements when this decline had become serious. Some of these are abandoning the work as conditions improve with a succession of wet years but a few will continue systematic observations that will become increasingly valuable with the passage of time. One of the most systematic of the irrigation companies has measured water plane fluctuations since 1892, and one of the most successful and thoughtful of the ranchers has carried out similar measurements since 1898. These isolated observations have been of great aid in the study of ground water problems, although neither is sufficiently long continued to serve as an entirely satisfactory basis for conclusions, because only one of the essential, greater undulations spanning a long period of drought is included in the fifteen years of measurements. It became necessary then, in order to suggest a wise policy for the users of ground waters in this region, to predict the tendency of this wave from such portions of it as had been developed.

The conclusion that ground waters were being used in excess because the level of the plane of saturation declined during a period of drought was as obviously unjustified as the prediction that they were not used as fully as they should be simply because it rose during periods of excessive precipitation. Therefore periods were selected from the records in which the rainfall was equal to or slightly in excess of the average and the behavior of the water plane was studied during these periods. It was found that in some instances declines had continued during such periods. It was considered in these cases that use was approaching the limit of safety, although it was recognized that conditions for the restoration of withdrawals would improve at an accelerating rate as rainfall mounted above the average, the relation between the acceleration and the percentage of excess

being undeterminable. This general fact of rapid improvement with heavy precipitation has been brought out in the records of the past three years, years of marked rainfall excess, and of marked recoveries in ground water levels in the favorably situated districts. The slow passage of the wave of recovery from the point of origin to remote parts of the basin, and its decreasing amplitude in this passage, however, have also been illustrated, and in a few cases, intervening developments in the form of pumping plants have been sufficient to destroy the wave, so that practically continuous declines have been observed in remote parts of a basin while sharp net recoveries are recorded in the vicinity of the most important sources of supply. When notable net losses have appeared during periods of rainfall in excess communities have been warned of the imminent danger of overuse. When ground water levels have remained substantially constant during periods of slight excess in precipitation, it is recognized that present use is not excessive. When recoveries are recorded during periods of average rainfall, further developments are permissible.

In general, it is recognized that most desirable evidence in the determination of the proper use of the ground waters in alluvial filled basins, that respond promptly to variations in the supply whether this supply be local rainfall or a stream that flows through the basin, is furnished by constant records of fluctuations in ground water levels, for comparison with the average rainfall, or the average flow of the supplying stream, and water users, whether individuals, corporations or municipalities, are advised to make systematically, the simple measurements necessary to supply this evidence. The city of Los Angeles is expending $25,000,000 in a new water supply after an exhaustive study of all possible cheaper supplies, and its determination to go 250 miles to the Sierras, is based in large part, upon evidence of the present full use of the available ground waters; evidence furnished principally by measurements of the fluctuations of ground water levels, but supplemented and confirmed by determinations of the shrinkage in the outline of artesian basins and the lessened yield of flowing wells.

THE MANGANESE ORE-DEPOSITS OF GEORGIA.

THOMAS L. WATSON.

INTRODUCTION.

This paper summarizes the principal facts embodied in two former publications by the writer[1] on the manganese ore-deposits of Georgia; one, published in the *Transactions of the American Institute of Mining Engineers* in 1904, the other, a state report published by the Geological Survey of Georgia in 1908. These publications were based on careful field study of the Georgia manganese deposits by the writer a few years ago, and it is thought that possibly a summary of the more important facts relating to the deposits, as contained more especially in the state report recently issued, might be of some interest.

DISTRIBUTION OF THE MANGANESE-ORES.

The manganese-ores in Georgia are limited in occurrence to the northern part of the state, distributed irregularly over parts of the Paleozoic and Crystalline areas. The commercially important deposits are confined to the Paleozoic area, which includes the ten northwest counties of the state, and are conveniently grouped into two principal districts, namely, (*a*) the Cartersville district, and (*b*) the Cave Spring district. These include Bartow, Floyd and Polk counties, with isolated scattered deposits occurring in other counties within the limits of the Paleozoic area.

The ores of the Paleozoic area occur in residual clays derived from the decay of several formations, namely, Weisner quartz-

[1] "Geological Relations of the Manganese Ore-deposits of Georgia," *Transactions Amer. Inst. Ming. Engrs.*, 1904, Vol. XXXIV., pp. 207–253, with 20 figures. "A Preliminary Report on the Manganese Deposits of Georgia." Geol. Survey of Georgia, Bull. No. 14, 1908, 195 pp., 8 plates, 2 maps, and 31 figures.

ite, Beaver limestone and Knox dolomite, of Cambro-Ordovician age.

Practically no mining has been done for manganese in the Crystalline area. Fifty tons would probably be a liberal estimate for the entire output in manganese-ores from this area. The ores are usually impure and much scattered, and are rarely concentrated in quantity sufficient to be workable. The ores of the Crystalline area show some variation in mode of occurrence from those of the Paleozoic area. Most of them occur, however, in residual clay derived from the decay of the crystalline schists, which, though of doubtful exact age, can be designated in part certainly as pre-Cambrian. No deposits of manganese are yet known to occur within the limits of the Coastal plain.

With but few exceptions, the manganese-ores of the two areas consist of the oxides of the metal. In several instances ores of a different mineral form have been found in the Crystalline area. Manganese-bearing silicate minerals enter somewhat largely into the composition of many of the various rock-types composing the Crystalline area, but wherever manganese has been observed in the decay of these rocks, it is, almost without exception, in the form of the oxides of the metal.

SUMMARY OF THE GEOLOGY OF THE PALEOZOIC AREA.

The Paleozoic area in Georgia forms a part of the southern extension of the Great Appalachian Valley southwestward into Alabama. It includes the northwest counties in the state, and is separated on the east and south from the Crystalline area by the Cartersville overthrust fault.

Topographically, the region forms a long, narrow belt in which the ridge-valley type predominates, the axis of which has a general northeast-southwest trend. When viewed in detail, it is made up of numerous subordinate valleys, separated more or less by extensive parallel ridges, whose axial directions are coincident with the general trend of the valley province. This ridge-valley type of topography bears a definite relation to the rock-structure of the area. The ridges mark the lines of more resistant rock, while the valleys are etched out of the soft shales and

limestones. According to the character of the rock, and the attitude and thickness of the beds, the ridges are high or low, broad and flat-topped, or narrow and sharp-crested.

The rocks of the region range in age from lower Cambrian to Carboniferous, and they include shales, limestones, slates, sandstones and conglomerates. No igneous rocks are yet known to occur within the limits of the area. The manganese deposits are limited to the residual decay resting on and derived from only three of the formations, namely, the Weisner quartzite, Beaver limestone, and Knox dolomite.

Structurally, the strata of the region have been folded and over much of the area fractured and faulted. To the northwest of the Coosa Valley the area is one of open folds, and faulting is less conspicuous. Folds of the anticlinal, synclinal, and monoclinal types are represented in many examples of northeast-southwest trending ridges preserved in the harder and more resistant rocks.

In the region to the south and southwest of Rome, the structure is more complicated, largely by reason of the folding having been quite or entirely obliterated by subsequent faulting, and by deposition overlaps and abrupt lithologic changes. Two classes of faults which differ from each other characterize the area, designated by Hayes as (*a*) major-thrust faults, and (*b*) minor-thrust faults. The former are characterized by great horizontal displacement and low inclination of the fault-plain. Three faults of this type have been recognized and described by Hayes in this area, namely, the Coosa, Rome and Cartersville overthrust faults.

The minor-thrust faults characterize the southern part of the area, especially the area immediately south of Rome and in the vicinity of Cave Spring, and are of the ordinary Appalachian type. They have an approximate north-south direction, intersecting the main axis of the region at angles of from 30 to 40 degrees, or thereabouts. In length they range from three to eight miles, and they cut the strata at close intervals into narrow strips, forming monoclinals, which dip steeply toward the east.

The faults bear no apparent relation to the manganese deposits of the region.

MINERALOGICAL FORMS OF ORE.

Only the oxides of manganese occur in the Georgia districts. Of these, pyrolusite and psilomelane greatly predominate, with some manganite and braunite, and much of the earthy oxide, wad. These usually occur admixed in varying proportions and cannot always be separated. The ore is of dark steel-blue color and much of it is crystalline. The nodular type nearly always displays the partial or completely layered or concentric structure, characteristic of concretionary masses.

ASSOCIATED ORE-DEPOSITS.

In the manganese districts of the Paleozoic area, extensive deposits of brown iron-ore, gray or specular hematite, yellow ocher, and, to a less extent, barite and bauxite, occur somewhat closely associated with the manganese ores. Of these the deposits of iron-ore, yellow ocher and bauxite have been extensively mined. Yellow ocher is mined only in the Cartersville district. Of the ores enumerated, bauxite is probably less closely associated with those of manganese than the others. Barite occurs in several localities in the Cartersville district, but as a rule it is not sufficiently concentrated to be profitably worked.[1] Several land lots in the Cartersville district, originally extensively worked for manganese, are at present being equally as profitably worked for yellow ocher. The shafts, cuts and tunnels opened for mining manganese are now used in part for mining the ocher, a fact that further emphasizes the intimate association of the two types of ores.

MANGANIFEROUS IRON-ORES.

The beds of limonite, which is the prevailing type of iron-ore in the Cartersville district, are usually distinct from, though occurring in close relation (side by side) with the manganese-ores. The oxides of iron and manganese are found at times admixed in different proportions in the same bed. Between the

[1] According to Hayes and Phalen, barite was mined near Cartersville, Georgia, in 1907. "A Commercial Occurrence of Barite near Cartersville, Ga." Bull. No. 340, U. S. Geol. Survey, 1908, pp. 458–462.

two extremes of pure iron-ore and pure manganese-ore occur all gradations in the admixture of the two oxides. In some beds of average thickness the two materials are homogeneously admixed, giving the appearance of a manganese ore when iron is present in small quantity, and of the usual limonite ore when manganese is in small quantity. Sometimes beds of iron-ore are found encrusted at the surface for only a slight depth with the oxide of manganese, which on being opened proves to be a good deposit of iron- and not of manganese-ore. Still a few other deposits have been observed which showed an interlamination of the two materials, layers of the iron-ore alternating with layers of the manganese-ore.

Chemical Composition.—Analyses of the iron-ores invariably show small percentages of manganese, and conversely the manganese-ores show varying percentages of iron, with intermediate gradations, in which the two oxides are nearly equal in amount, forming a good grade of manganiferous iron-ore. These gradations are shown to some degree in the following partial analyses of ores from the Cartersville district, Ga.

ANALYSES OF MANGANESE- AND IRON-ORES, CARTERSVILLE DISTRICT, GEORGIA.

Manganese	60.610	56.400	54.940	47.19	46.510
Iron	1.450	1.290	3.620	10.22	3.300
Phosphorus	0.052	0.158	0.034	0.28	0.055
Manganese	36.00	35.320	25.090	15.260	2.30
Iron	16.88	3.110	29.170	39.250	52.02
Phosphorus	0.14	0.063	0.155	0.193	0.24
Manganese	2.254	1.870	1.520	0.382	
Iron	51.170	56.680	52.190	54.570	
Phosphorus	1.045	0.864	1.036	0.722	

The average in metallic manganese in the better grade ores is uniformly high, with correspondingly low iron, silica and phosphorus. Silica usually averages low in those cases where the ore has been properly cleansed. It rarely ranges above 10 per cent., and is usually much below this, averaging from 2 to 5 per cent. In many of the lower grade ores the silica averages considerably more than 10 per cent. High silica is particularly

noticeable in many analyses of the ores mined in the early period of development. This was largely due to the operators shipping the ore direct from the mines with little or no previous cleansing.

The phosphorus content in the worked Georgia ores is rarely high enough to detract from the value of the ore. Usually, the manganese-ores are characterized by a low phosphorus percentage. The average in this ingredient for the better grade ores is from 0.10 to 0.15 per cent., rarely rising above 0.25 per cent.

RESIDUAL DECAY.

The clay in which the manganese-ores are assembled represents the residual decay from weathering of the Weisner quartzite and Beaver limestone in the Cartersville district, and of the Knox dolomite in the Cave Spring and other districts in the Paleozoic area. The decay derived from the several formations can be differentiated frequently on the basis of composition, texture and color. The depth of the rock decay varies greatly. It is dependent, other things being equal, on the character of the rock and on the attitude of the rock strata.

In the Cartersville district the Weisner quartzite has been much broken and crushed, and is thrown into a series of narrow, more or less steep folds or ridges. The tops and slopes of the ridges, as well as the valley bottoms, are covered to some depth with the quartzite decay. Reefs of the hard rock are often exposed along the crest of the ridges, and to some extent exposures are frequent near the tops and along the steeper slopes of the ridges. In several places shafts have penetrated to a depth of several hundred feet without piercing the bed-rock. Depths of 100 feet and more in the residual decay are common.

In the Cave Spring district the decay derived from the Knox dolomite is very variable in depth. In places the moderately fresh cherty limestone is exposed as broken reefs on the ridge-tops. In other places on the ridge-tops excavations in mining expose the hard rock at depths varying from 12 to 30 feet; and in still other places, on the same ridges, rock is not encountered at depths of 50 and 60 feet.

Massive cherty layers or beds and nodules are of more frequent occurrence in the Cave Spring district than in other areas of the Knox formation in northwest Georgia. Here the chert attains considerable thickness, and almost entirely replaces the limestone in places. The relation of the chert and limestone is well illustrated along the ridges to the southeast of the town of Cave Spring.

MODE OF OCCURRENCE.

In the Cartersville district the manganese-ores occur imbedded in the heavy mantle of residual clays derived from the decay of the Beaver limestone and the Weisner quartzite, and they have nearly equal distribution in the decay derived from the two formations. The residual decay of the Weisner quartzite is a light gray to yellow siliceous clay admixed with quartzite fragments in all stages of decay; that of the Beaver limestone is a deep red clay less siliceous than that derived from the Weisner quartzite but admixed with some chert fragments, and near its outer margin, in contact with the Weisner formation, additional fragments of the latter rock occur.

In the Cave Spring district the ores have a similar occurrence as in the Cartersville district, but are associated with clays derived from a limestone which belongs stratigraphically above the Beaver limestone and the Weisner quartzite. Here they are imbedded in the cherty clays derived from the Knox dolomite. In the smaller scattered districts over the Paleozoic area the occurrence of the ore is the same as for the districts already described, usually in the decay of the Knox dolomite.

The ore is very irregularly distributed in the clays in small pockets, rarely in distinct beds; in the form of veins and stringers penetrating the clay in all directions; as single nodules or concretionary masses of various sizes and shapes assembled in the clays; and as small disseminated grains scattered through the clay. At times the ore distribution in the clays conforms in a general way to the bedding of the inclosing clays; more often, however, this is obscured and the ore-bodies indiscriminately cut in all directions.

The ore-bearing pockets vary greatly in size and numbers. In size they range from small nests to bodies six and more feet thick, and more than thirty feet long, and in extreme cases may yield several hundred tons of ore. They are rarely composed of solid ore free from the surrounding clay, their usual form being that of somewhat thickly-studded nodules in the clays. The pockets may occur close together, or far apart, and are usually not connected, but in many cases irregular stringers and small veins are observed to lead from one pocket to another.

The ores are rarely entirely free from admixtures of the inclosing clays, a condition which naturally results from their method of concentration. Some of the ores are freer from these mechanical impurities than others. The proportion of clay to ore is usually larger than in the closely associated brown iron-ores.

GENESIS OF THE MANGANESE-ORES.

The distribution of the manganese-ores has been shown to be in the decay derived from the Weisner quartzite, Beaver limestone and Knox dolomite, of Cambro-Ordovician age. The distribution, occurrence and nature of the ores preclude any connection or relationship to the larger structural features of the region. The closely associated ore-deposits, more especially limonite,[1] yellow ocher[2] and bauxite,[3] with those of manganese,[4] have been shown to bear no genetic relationship to each other.

The immediate source of the manganese was the rocks from which the residual decay inclosing the ores was derived by weathering. Accumulation was not necessarily limited to the manganese contained in any one of the formations in whose residual decay the ores now exist, but may have been derived from any

[1] Hayes, C. W., *Trans. Amer. Inst. Mng. Engrs.*, 1901, Vol. XXX., p. 411, *et seq.* McCallie, S. W., Bull. Geol. Surv. of Georgia, No. 10, 1900, pp. 19–26.

[2] Watson, Thos. L., *Trans. Amer. Inst. Mng. Engrs.*, 1904, Vol. XXXIV., pp. 659–663. Bull. Geol Surv. of Georgia, No. 13, 1906, pp. 57–65.

[3] Hayes, C. W., 16th Ann. Rpt. U. S. Geol. Surv., 1895, Pt. III., pp. 587–591. Watson, Thos. L., *Amer. Geol.*, 1901, Vol. XXVIII., pp. 38–45. Bull. Geol. Surv. of Georgia, No. 11, 1904, p. 169.

[4] Watson, Thos. L., *Trans. Amer. Inst. Mng. Engrs.*, 1904, Vol. XXXIV., pp. 237–245. Bull. Geol. Surv. of Georgia, No. 14, 1908, pp. 145–157.

formations containing this element, formerly covering the one in which the ores are now found. There is field evidence in certain areas to support this statement.

The Paleozoic rocks are bordered on the east and south by older crystalline rocks from which the former rocks were largely derived. These crystalline rocks, made up in part of original igneous masses and in part of original sedimentaries, are composed of numerous complex silicates, some of which are manganese-bearing. It was from these older crystalline rocks, during decay, that the manganese is believed to have been originally derived.

Rock decay in the southern region has been promoted largely by chemical changes in the rock-forming minerals, resulting in new mineral combinations of simpler and more stable forms. Accompanying such changes, the bases of the silicates combine with the various acids and are removed in solution as salts of these acids, the insoluble parts of the minerals remaining where formed, to make up the residual mantle. Manganese, with other of the base-forming elements, is thus removed in solution by the streams, and under favorable conditions of oxidation is finally precipitated with the sediments on the floor of the water-bodies into which the streams drain.

If, as indicated, the manganese was regularly or irregularly disseminated in a finely divided state through the limestones and quartzites in greater or less quantity, then some secondary action or process must explain their present local accumulation. Segregation to any appreciable extent, if at all, of the finely disseminated particles of manganese does not appear to have taken place in the original unweathered rock. The agencies which promoted the decay of the rocks inclosing the manganese particles were those involved in the accumulation of the ores in their present concentrated form. The process involved in the local accumulation was largely one of resolution of the manganese by the acidulated surface waters and its precipitation in another position in the residual clays.

The irregular distribution of the ores, both laterally and vertically in the residual clays; the frequency with which the ore-

bodies are observed to cut across the bedding of the inclosing clays, and without regard to orientation in any direction; the invariable presence of greater or less quantities of included quartz grains and other particles of siliceous material irregularly distributed through the nodules and masses of ore, of the same character as that composing the inclosing clays; the concretionary nodular and stalactitic forms of the ore; and its prevailing tendency to crystalline structure are the most pronounced features of the ores, and are those which would result from such a process of segregation as outlined. That is, they are secondary accumulations, resulting from chemical and physical action during the decay of the rocks containing the manganese.

Abundant masses of breccia ore are associated to some extent with other types of the ore, in all of the deposits, but they are especially characteristic of the lower zone of decay of the quartzite, which consists of only partially decayed and broken masses of the rock over the quartzite area. The formation of the breccia masses is due to the downward percolation of the manganiferous solutions through the overlying mantle of decay into the cracks and crevices separating the rock-fragments and deposition of the manganese oxide. In the Cave Spring district, where broken masses and beds of chert from the Knox dolomite abound, a similar formation of chert breccia is observed. In some instances the percolation from above has extended into the cracks of the moderately fresh rock below, with deposition of manganese forming intersecting veins in the rock.

PRODUCTION.

The total production of manganese-ores in Georgia from 1866 to 1906, inclusive, was 92,244 long tons.[1] This production is exceeded only by that of the State of Virginia. Since the close of the year 1902 the production of manganese-ores in Georgia has been very small: In 1903, 500 tons; in 1904, none; in 1905, 150 tons; in 1906, none. According to E. C. Harder,[2] Georgia was not on the list of producers in 1907.

[1] "Mineral Resources of the United States," 1905, p. 93.

[2] "The Production of Manganese Ores in 1907." Advance chapter from Mineral Resources of the United States. Calendar year 1907, p. 7.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

THE LOCALIZATION OF VALUES IN ORE-BODIES AND THE OCCURRENCE OF SHOOTS IN METALLIFEROUS DEPOSITS.

ORE SHOOTS.

Sir: After the excellent papers on the subject of ore shoots which have been contributed to this discussion during the last year I feel there is but little to add. In the second number Mr. F. C. Smith has well indicated the difficulties that stand in the way of a systematic treatment of ore shoots. So many causes influence them that generalizations, however carefully established for certain districts, are very apt to crumble to pieces when subjected to tests in other localities. The behavior of the shoots may be summed up in the words that "sometimes they do and sometimes they don't"; and particularly often they fail to materialize when in accordance with supposition they should do so. One recalls the rule of following the striations on the wall; the rule of pitching in certain directions; the rule of intersections, etc. The latter is perhaps the most generally satisfactory, but the satisfaction is tempered by the experience that while enrichment often happens, sometimes it does not.

Professor Irving's contribution in the first number of 1908 is valuable in systematizing the occurrence of primary ore shoots; the secondary ores are excluded from his discussion. This is, of

course, justified in a way, but as the latter often form the most valuable part of a deposit they must be considered. Mr. H. V. Winchell in the fourth number for 1908 takes these into consideration and introduces for them the term of "post-genetic"—a word clearly open to the objection that migrations may establish the secondary shoot in a previously barren place, giving it a distinctly new "Genesis." Moreover, he includes in the post-genetic shoots those caused by any later movements or rearrangements in the vein, later than the epoch of earliest deposition. It seems to me it would be better to make a separate class of the shoots formed by descending surface waters and simply call them vadose shoots. Mr. Winchell aptly refers to shoots of this kind as similar to the outlines of a saw, when projected on the plane of the vein. The vadose shoots are in fact usually characterized by *horizontal* extension, in contradistinction to the predominance of the vertical direction in the primary shoots. It is not necessary to go into the well-known mineralogical characteristics of the vadose shoots. Their tendency is to spread along the strike of the vein, often also out into the wall rock. Thus pay ore will often be found for long distance following the vein and the appearance will be that of the oxidized croppings of a long primary shoot, when in fact deeper explorations will often prove the existence of a few narrow primary ore bodies underneath the continuous vadose ore. Sometimes, as in Calico, San Bernardino County, California, and numberless other places, vadose silver ores will be found in the croppings along a vein which simply are a concentration of a primary vein filling containing no workable shoots. Especially in case of copper ores, depth is also an important factor in vadose shoots with the various zones of surface impoverishment, oxidized belt and zone of secondary sulphides, but the tendency to lateral spreading is always emphasized. Wandering copper solutions, for instance, find in adjacent shale beds congenial places for precipitation of oxide and entirely new ore shoots are formed.

In the place mentioned Mr. Winchell has excellently portrayed the many vicissitudes to which deposits have been exposed and the extent to which changes take place in the original deposit.

While this is undoubtedly true in many cases there is a danger of laying undue stress on such processes. In our western territory the majority of deposits have suffered little change since deposition, excepting by the working over by vadose waters. The majority were formed in late Cretaceous or in Tertiary times and no great epochs of dynamic stress and metamorphism have, as a rule, affected them. The remarks apply, however, without doubt to deposits of pre-Cambrian age, which are sparsely scattered through the west and which are more common in the east. There are instances of this kind (one of them is the Sedalia mine in Colorado, p. 161, Bulletin No. 340, U. S. Geol. Surv.) where the original deposit probably consisted of sulphides segregated from a molten diabase magma. Subsequent dynamo metamorphism changed this deposit to an elongated body of chalcopyrite and zincblende in amphibolitic schists. Descending surface waters finally extracted the zinc from the upper part of the deposit and distributed the copper ores in oxidized form through a great thickness of altered schist. It is my belief that many of the obscure copper deposits in amphibolite schists have undergone this series of changes. In a case like this we can differentiate a magmatic segregation shoot; a metamorphic shoot; and a vadose shoot.

The terminology of shoots as ordinarily used is rather vague. Mr. Ransome and I in a recent report on the Cripple Creek district suggested the following terms which we still believe suitable for use. *Pitch length,* or axial length, is the distance between the two extreme ends of the shoot; the *pitch* is the angle which the pitch length makes with the strike of the vein, and is measured on the plane of the vein. A recent discussion in the Transactions of the American Institute of Mining Engineers between Dr. Raymond and Professor Louis brought to light some diversity of opinion regarding this definition. As stated by Dr. Raymond the American usage is so well established that it would be very unwise to change it. The *stope length* is the horizontal length of the ore shoot on any particular level. The *thickness* or *width* is measured perpendicularly to the plane of the vein.

The *breadth* of the ore shoot is the stope length multiplied by the sine of the pitch.

At the same time there is undoubtedly a need for a term which will express the angle of inclination of the axial length of a shoot measured in a vertical plane. More especially it is needed for lenticular ore bodies, say of pyrite or magnetite, which have a certain extension in strike in a horizontal plane, while the most important structural feature is this inclination in a vertical plane. The Swedish miners have long had an expression to cover this, namely, "stupning i fält" or "dip in the extension of the field." For this Professor Louis proposes the term "pitch." Mr. A. C. Spencer, of the Geological Survey,[1] proposes to use the term "*plunge*" for this angle which the pitch length of a shoot makes in a vertical plane with the horizontal, and the word, it seems to me, is well chosen.

In ore shoots formed by upward moving waters the impounding of these by impervious strata or by gouge seams is surely a most important factor; a great number of deposits show the influence of this. In addition to the examples already given in previous numbers of the journal, I would like to mention the remarkable part played by a thin formation of Devonian shales in some mining districts of southern New Mexico recently investigated for the Geological Survey by Dr. C. H. Gordon. Over a large territory the galena-shoots in limestone are found immediately below this impermeable stratum.

In Professor Irving's letter in the first number of 1908, a classification of shoots was proposed and this constituted a decided step in advance. However, I think it inadvisable to include shoots of all kinds of deposits in this scheme. A shoot in an igneous mass is essentially different from one in metamorphic schists, and that again differs radically from a shoot in a fissure vein, lode or shear zone.

In deposits which follow fractures, the distinction between *shoots of occurrence* and *shoots of variation* as proposed by Professor Irving does not seem to be an essential one and still less is it applicable to all kinds of deposits. At Grass Valley, for

[1] Oral communication.

example, some shoots coincide with the filled portion of the fissure, which others, possibly in the same vein, form columns in a continuous quartz-filled sheet.

As far as any generalizations can be made of shoots in veins, the greater extension in depth than in lateral dimensions should first be noted. At Cripple Creek the opportunity was given to examine a very large number of shoots. The normal form is elongated, vertical or pitching steeply, the ratio of vertical to horizontal extension varying from 1.5 : 1 to 5 : 1.

As to primary distrinbution of ore we have in fissure veins in general several relations: (1) The lenticular-gradational shoot with a rich core and gradually fading values. The Holy Terror, described by Mr. F. C. Smith in the second number of ECONOMIC GEOLOGY for 1908, and the shoots of the Kalgoorlie shear zones, described by Mr. H. C. Hoover offer examples of this. I have often thought that this class of ore bodies is especially common in fissure veins of pre-Cambrian age, but this may prove a generalization of doubtful value. (2) The columnar—confined shoots, in which the values are fairly uniform and cease rather suddenly along the outlines; this is often caused by the closing of the vein, but it is also common to find the values suddenly fade while the normal gangue or filling continues without change. Other kinds of vein shoots could undoubtedly be added.

Considered in cross-section some shoots, as well known, occupy the entire thickness of the vein, but a very important class is formed by the imbricated shoots following certain fracture lines within the vein and jumping with overlap from one to the other. Such imbricating shoots may be a result of the primary processes of vein filling or they may be formed by the fissuring of a primary lean filling and by the resumption of ascending circulation with attendant enrichment. It might be advisable to refer to these classes as shoots of initial and resumed mineralization. The great Cracker Creek lode near Sumpter, Ore., appears to offer an excellent example of the latter class, and I wish I could prevail upon Mr. E. Melzer, who has studied it for many years, to give us a full description of its interesting features.

Considered in causal relation we can probably not do better

than to follow Professor Irving's division in vein shoots due to intersections, to impounding, to chemical effect of wall rock, and to general decrease of pressure and temperature.

The general conclusion would be that a classification of the ore shoots in general should be preceded by a division into magmatic segregation shoots, metamorphic shoots, replacement shoots, shoots of ascending circulation, and vadose shoots. Each of these can then be further subdivided.

WALDEMAR LINDGREN.

REVIEWS

Rocks and Rock Minerals, A Manual of the Elements of Petrology Without the Use of the Microscope. By Louis V. Pirsson. 12mo. 414 pp., with 36 plates and 74 text-figures. New York and London, 1908.

Probably each reader of this review will have asked or will have many times heard the question "What is the best book on rocks for one who is not a specialist and who has no knowledge of microscopical methods?" After splitting up the rock groups into almost countless varieties and after redefining old names and applying new ones until the resulting classification and nomenclature threatens disintegration, the petrographer, thanks to the present admirable little volume, no longer need confess that he and his colleagues have neglected to provide those who deal with rocks in a practical way with any substitute for the old and simple terminology of which the struggles and progress of science have deprived them. Of late years some of the leading petrographers in America have realized the necessity of a return, for practical and field purposes, to a simpler grouping of rocks while insisting at the same time on more accurate and rational classification for purely scientific purposes. Professor Pirsson's book is to be regarded as a successful outcome of this tendency.

The work is divided into three parts: (1) A short general introduction on the scope, history and methods of petrology and on the chemical character of the earth's crust. (2) A section on the important rock-making minerals. (3) A section on the rocks themselves. This last occupies about three fourths of the book and contains chapters on: (1) "The General Petrology of Igneous Rocks. (2) "Descriptions of Igneous Rocks." (3) "The Origin and Classification of Stratified Rocks." (4) "Descriptions of Stratified Rocks." (5) "The Origin, General Characters and Classification of the Metamorphic Rocks." (6) "Descriptions of Metamorphic Rocks," and (7) "The Determination of Rocks."

The chapter on the general petrology of igneous rocks treats clearly and concisely of their distinguishing characteristics, of their modes of occurrence, of their chemistry, mineralogy and textures, of some of their structures, of petrographical provinces, of post-intrusive processes and

of classification. Under the last head is presented a simple grouping based primarily on such textural and mineralogical features as can be determined in the field. Thus all igneous rocks are divided into three main classes on the basis of texture: A, Grained; B, Dense, and C, Glassy. Each of these classes has its non-porphyritic and porphyritic groups and each of these groups in classes A and B is in turn divided into (*a*) feldspathic rocks and (*b*) ferromagnesian rocks. Further subdivision of the grained rocks is based on the presence or absence of quartz and on the ratio of feldspars to ferromagnesian constituents. The simplicity of the classification becomes apparent when it is stated that the non-porphyritic grained rocks are distributed under the heads of Granite, Syenite, Diorite, Gabbro, Dolerite and Peridotite.

In the chapter on the description of igneous rocks the composition, texture, color, varieties, physical properties, uses, structures, contact phenomena, weathering and occurrence of each rock type receive treatment that is clear and adequate yet which is never so detailed as to be inconsistent with the purpose of the book.

The stratified rocks are classified on the basis of origin and are treated in a similar manner and with the same good judgment and restraint as mark the section on igneous rocks.

In dealing with that difficult class the metamorphic rocks the author points out the manifold derivation and the countless gradations of these. He summarizes existing knowledge on the processes whereby igneous and sedimentary rocks are converted into metamorphic rocks and describes the chemical composition, principal minerals and characteristic textures of this class. He concludes that it is necessary "for practical purposes of field work and megascopic determination, to classify quite arbitrarily the metamorphic rocks according to their evident mineral composition or texture, or a combination of both." Nine groups are made and the rocks of these are then described in a manner similar to that adopted for the igneous and stratified classes.

The last chapter contains some general considerations on the field determination of rocks and a table, adapted from Geikie, for the identification of the commoner sorts.

Those petrographers who hesitate to relinquish the older scheme of classification in favor of the quantitative system of Cross, Iddings, Pirsson and Washington will naturally look with disfavor on the proposal to revert to the original broad usage of terms like *granite* and *basalt*. The proposal, indeed, may be regarded as a minor flank movement on the part of the quantitative adherents which threatens the conservatives by cutting off some of their supplies. The economic geologist, also being under the necessity of writing so as to be intelligible to men who are not petrologists, is unable to use the quantitative system

alone and is yet scarce likely to be satisfied with so simple a grouping as is offered in the present volume. He is thus perforce a conservative in nomenclature unable to adopt unreservedly in practice all that appeals to him as sound in principle. Notwithstanding these grounds of objection, the reviewer believes that the proposition to restore to the old familiar rock names the broader meanings which they had before the use of the petrographical microscope is a sound one and will ultimately prevail. In the meantime some confusion and inconvenience is unavoidable.

The book throughout is very well balanced. It is clear that Mr. Pirsson is too experienced a teacher to underestimate the peculiar difficulties in the way of the elementary presentation of a difficult subject. The work indeed bears evidence of the same care and accuracy that distinguish his more rigidly scientific papers and is remarkably free from the slipshod statements and inexcusable blunders that disfigure too many text-books.

In anticipation of future editions the reviewer ventures a few suggestions. In the general table of classification of igneous rocks (page 202) the dense rocks are divided into "(*a*) Light-colored, usually feldspathic" and "(*b*) Dark-colored to black, usually ferromagnesian," (*a*) and (*b*) corresponding to felsite and basalt respectively. Undue prominence seems here given to color. The author intends, as appears later, to include dacites and andesites under *felsite*. As a matter of fact, however, many of these rocks are nearly as dark as basalts. It would perhaps be better to say" (*a*) Feldspathic, usually light-colored," etc., and to add a statement as to the densities of non-vesicular rocks of the two groups. The rough determination of the latter property does not require elaborate apparatus.

Experience in mining regions shows that the distinction between fresh rock and altered rock is seldom appreciated by men with no special petrographic training. Some space might well be devoted to the changes effected in the color and appearance of rocks in connection with ore deposition. These are often marked and characteristic as in the case of the sericitic and calcitic alteration along the gold belt of California and the alunitic alteration at Goldfield, Nevada. The engineer and economic geologist must perforce deal with such altered material which the petrologist naturally tends to avoid. The fact that the proposed classifiication is based on the properties of *fresh* rocks should be emphasized.

As regards minor matters, the use of *natural* to designate those colors in minerals which depend upon their ideal chemical composition whereas those tints due to incidental inclusion of pigments or to non-essential coloring matter (as manganese oxide in amethystine quartz) are termed

exotic is not happy. The presence of incidental or non-essential coloring is, if anything, more *natural* than its absence. *Indigenous* or *inherent* would probably be a better word than *natural* in this connection. On pages 154–155 igneous rocks are classified as Phanerocrystalline, Dense and Glassy, while on pages 194–195 the classes are given as Grained, Dense and Glassy, the author remarking truly in a footnote that the simple English word *grained* is better than *phanerocrystalline*. The retention of the latter formidable word in the first place cited is probably an oversight.

The book is sensibly printed and bound and is practically free from typographical errors. It may be unreservedly recommended as fulfilling the useful purpose for which it was written.

F. L. RANSOME.

Die Untersuchung und Bewertung von Erzlagerstätten. Von Professor Dr. P. KRUSCH. Pp. 517 and 102 text figures. Stuttgart, Verlag om Ferdinand Enke, 1907.

The title of this translated into English would be: "The Examination and Valuation of Ore Deposits." Its author is a geologist in the Prussian Geological Survey and a teacher of the science of ore deposits at the mining school of Berlin. As stated in the introduction it is his aim to combine in this book the modern geological data of ore deposits, with a description of methods of prospecting, concentrating and marketing of ore and with a résumé of the statistical data of the mining countries of the world. This is an ambitious program and one which could only be successfully carried out by a man of wide acquaintance with the mining regions of the world. The book gives evidence that with all his undoubted accomplishments Dr. Krusch does not possess this cosmopolitan familiarity.

The general part of one hundred pages consists first of fifty pages treating of the formation of minerals and of mineral deposits as well as of the classification of the ore deposits. The treatment is necessarily brief, but this is in general one of the best parts of the book. In its principal features the classification follows a volume on ore deposits, soon to be published, by Beyschlag, Vogt and Krusch.

The chapter on prospecting by boring follows, and, in view of the importance of the subject, the treatment is inadequate. The chapter on concentration, although open to much criticism, is more complete.

The next fifteen pages discuss the methods of sampling and valuation. This part could have been expanded with benefit, and the author might have found much to interest him and his readers in the little volume on "Mine Sampling" edited by Mr. T. A. Rickard. In a list of periodicals devoted to mining geology ECONOMIC GEOLOGY finds no mention.

In the next two hundred pages the ores and deposits are discussed by metals. Gold is first taken up and its ores described, especially the tellurides. The sulphuric acid test of tellurium is given, but without caution as to its failure when the minerals are intergrown with pyrite.

Gold quartz veins with native gold as chief primary ore mineral are not recognized, and the author evidently has the impression that no such class exists. On the other hand he has found that gold, like copper, is dissolved and re-deposited in lower zones. His pyritic gold veins have a zone of oxidation which is relatively barren and a zone of cementation which contains the leached gold values from the upper levels. It is hardly necessary to point out that the experience in the United States and in other countries does not agree with the view of such a rapid and wholesale transportation of the gold. Our experience is rather that, except in rare cases, the gold is not dissolved and re-precipitated as readily as copper and silver.

Other likewise very doubtful generalizations might be pointed out. For instance, it is stated as a general rule that in telluride veins the secondary zone is impoverished and may contain less than half of the gold in the primary zone. This conclusion, derived from Western Australia, does not accord with the character of the oxidized zone at Cripple Creek.

The chapter on placers is especially unsatisfactory. Dredging is apparently the only process considered. The cyanide process is stated to be of importance in working placers. A part of the gold is considered as secondary and deposited by solutions in the placer ground. The gold in the crevices of bedrock is derived by solution and re-deposited from the placer gold above. The old incorrect statement is repeated that free gold of the dimensions of the large nuggets of the placers have not yet been found in primary deposits.

Copper comes next, and one of the first statements is that contact metamorphic deposits containing copper are of rare occurrence and unimportant. This is obviously incorrect.

The copper ores of Lake Superior are stated to be rather rich, containing up to 7 per cent. copper. In contra distinction the similar copper ores of New Guinea are said to contain only about 1 per cent.

The chapters on copper, iron, lead and zinc are in general better than that on gold. Among odd statements that may interest American readers is one that the ores of Joplin average 58 per cent. zinc. In this case concentrates have been mistaken for ore. We are also told that important zinc ores are derived from the Cœur d'Alene mine in the Wood River district.

The latter third of the book is statistical, and, as far as the United States is concerned, consists of more or less carefully selected extracts from *Mineral Industry*.

No doubt the volume contains many important data and may be useful to German readers. In its present form it cannot be recommended to American mining engineers. The plan is, however, a good one and it is to be hoped that the serious defects will be remedied in the second edition.

W. LINDGREN.

A Treatise on Gold and Silver. By W. R. CRANE. New York, Wiley & Sons, 1908.

The present volume, as its preface informs us, "has been prepared with aid from the Carnegie Institution," and is intended to form part of an economic history of the United States, now in course of preparation by the Department of Economics and Sociology of that institution.

The search for and discovery of the precious metals and the winning of these metals from their ores have been fundamental factors in the phenomenal development of the mineral resources of our continent, and an authoritative and philosophic history, such as might be expected in a work prepared under these auspices, should prove of great value to the student, and of absorbing interest to the general reader.

Hence the present work will receive a more extended and critical notice from the reviewer than the general character of a book prepared as this evidently has been, by piecing together clippings largely from the technical press, would otherwise have called for.

The author, who is instructor in mining at Columbia University, says that he has devoted two years to this work, and his conception of the objects to be aimed at, as outlined in his preface and chapter headings, is intelligent and comprehensive. He has, however, been hampered by the vastness of the material to be handled and by the bad method of handling which has been adopted.

The book opens with a brief chapter on the influence of precious metal mining on civilization, agriculture, transportation, mining schools, etc. Then follow chapters on the discovery and occurrence of gold and silver, and on the mining and reduction of their ores, which fill 500 out of the 700 pages in the book, the balance being given to tables.

In the opening chapter, in which one would look for a philosophic summary of the facts contained in the whole book, the defects of the scrap-book method of compilation, as it might be termed, are readily apparent, the results being rather desultory and inconsequent.

The subject of Chapter II., "Discovery," lends itself more readily to this method, but the author displays a dangerous fondness for repeating miners' yarns (in pp. 23, 46, 73) which have not much more foundation in fact and less charm of style than Bret Harte's stories. The printed matter in this and in the following chapter is arranged

alphabetically by states, rather than geographically, so that it presents no consecutive connection, nor does the author help the reader by general summaries, though he often makes unnecessary repetition of the same material in both chapters. As an extreme instance may be mentioned a brief paragraph about the Mt. Glines mine in Oxford County, Maine, to the effect that though the ore was reported to carry gold, an examination by geologists of the United States Geological Survey proved it to contain none. This important piece of information is given in slightly differing form under Discovery (p. 78), Occurrence (p. 236), and Production (p. 646).

To Chapter III., on the "Occurrence of Gold and Silver," which is the subject with which the reviewer is most familiar, later criticism will be mainly devoted.

In Chapters IV. and V., on the mining and reduction of Ores ("Extraction of Values"), being subjects with which the author should be most familiar, one would expect summaries of the improvements in method and their effect on the industry in general in his own words, but the scrap-book method is still employed, the proportion of quotations being seemingly greater than in the other chapters.

The tables of production are necessarily taken from other publications, and this chapter is to be criticized only in regard to the choice of these tables and the absence of any general deductions by the author from the facts presented in the tables.

Sources of Information.—The author often quotes old publications which have been supplanted by later and more thorough work, and frequently takes excerpts from articles in the periodical press when he would have done better to have consulted the original source from which the authors of these articles got their facts. Thus in Chapter III., under *Alaska*. Brooks's first report is cited, but the later annual reports of himself and assistants, which more or less superseded this, are ignored, and, while Dawson and Becker are quoted with reference to the Treadwell Lode, the later works of Palache and Spencer are not mentioned. As a result, practically nothing is given in regard to Fairbanks, the most important district in the whole territory.

Under *Canada* a long extract on Silver Islet is given, but nothing in regard to the more important silver deposits of Cobalt.

Under *California* no reference is made to the work of Ransome, Turner and Lindgren on the Mother Lode.

Under *Colorado,* for the San Juan region, while Comstock's theory of radial ore deposition (1885), which later observers considered visionary, is fully given, no reference is made to the recent and systematic work of Cross, Purington and Ransome.

For Custer County the report of Cross and Emmons is ignored, while

a very erroneous description of the Bassic (sic) and other mines is taken from the Colliery Engineer and Mines and Minerals.

Other original sources not consulted are: for *Idaho,* Ransome's report on the Cœur d'Alene region—for *Montana,* the Butte Folio, by Emmons, Weed and Tower—for *Nevada,* Becker's Monograph on the Comstock Lode, and Spurr, Ransome, Garrey and Emmons' reports on the Tonopah, Goldfield, and Bullfrog districts, and finally under *South Dakota,* Irving's report on the Mineral Resources of the Black Hills.

Selection of Material.—In his selection of material for citations, and his rather haphazard arrangement of this material, the author displays a signal want of discrimination and of sense of proportion, together with an apparent unfamiliarity with actual conditions in the mining districts of the west. In illustration of the above, a few typical instances of misleading statements, omissions and errors will be cited.

Thus from his "General Discussion" of the manner of occurrence of gold, the following sentences are culled (p. 164):

"Gold may be found in any formation, and in fact in practically any geological age. . . ."

"The famous mine of Guanajuato, the most productive of Mexico, and which yields one quarter of its product of silver, intersects sandstones and shales."

"Sulphides occasionally occur alone in nature, but an occurrence which is by far more common is where several are associated together."

"Pyrolusite, or ruby silver, is a compound of arsenic, sulphur, and silver. . . ." "It occurred in the famous Granite Mountain mine, Montana. . . ."

Of the Campbird mine in Colorado it is said (p. 215): "It is evident both from observation within this and neighboring mines, that the veins vary but little in depth even to a depth of 2,000 feet, . . ." and a little below, of the same mine: "They (the ore bodies) have been worked to a depth of 800 feet."

With regard to the Leadville mines, the following are some of the statements made. Of the seven formations in the district (p. 210), the "sixth, is an overflow of porphyry which comes in contact with the ore bodies below, and seventh, a deposit of glacial wash also containing ore." Again, "At a depth of 600 feet below the oxidation zone, the ores are largely siliceous in character, being stained with oxides. . . ." and later, ". . . fully 80 per cent. of the value is gold."

Of the Downtown mines at Leadville, which have never yielded more than a trace of gold, it is said: "When the depression, due to financial conditions following the depreciation of silver, was felt the mines adapted themselves to the new conditions by becoming gold producers."

Minor errors abound, such as giving 1874 instead of 1873 for the

discovery of gold in the Cassiar district, Alaska (p. 36); 1855 for 1863 as the date of building the Mullan road in Idaho (p. 73); Furnis Creek instead of Furnace Creek, Death Valley.

Prouse Kelly and John Orr (p. 86) are given as discoverers of the Comstock Lode, instead of William Prouse, followed later by John Orr and Nicholas Kelly.

Under *Montana* (p. 243) it is said: "The Granite Mountain lode is a blanket-vein lying between hard quartzite walls," whereas it is well known to be a typical fissure vein in granite country rock.

Ignorance of geography is displayed in such statements as this (p. 267):

"Bingham and Big and Little Cottonwood Cañons constitute the oldest district of the state. It is situated in the northern central part of the state on the eastern slope of he Oquirrh Mountains. . . ." The two Cottonwood Cañons, as every one who has visited Utah knows, are in the Wasatch Mountains over twenty miles distant from Bingham.

The *technical arrangement* of the book is very unsystematic. The same type is used for all side headings, irrespective of the importance or comprehensiveness of the title. Thus Canada follows Inyo County (pp. 192–4) as of the same value, while more general subjects such as "Permanence in Depth," etc., are generally given as side headings (p. 280), sometimes as middle headings in italics (pp. 171, 289, 329), small (p. 357) or large (pp. 356, 470, 496) capitals, as the case may be.

The references, so important in a work of this kind, are sometimes given in the text, but generally as footnotes. Among the latter those relating to the periodical press, which are the most numerous, give neither authors, titles, nor dates of publication. The excerpts in the text are in some cases enclosed by quotation marks, but for the most part are not differentiated from the rest of the text, so that it is practically impossible to distinguish the words of the author from those of his authorities.

What is called a bibliography appears to be simply a casual memorandum of publications which the author happened to consult, often bare titles without other information, and arranged neither in alphabetical nor in chronological order.

Out of twenty-nine illustrations, in which plates and figures are not differentiated, eighteen are taken from *Mines and Minerals,* five from the *Mining and Scientific Press* four from the *Engineering and Mining Journal,* and one from the *Transactions of the American Institute of Mining Engineers.* This is somewhat indicative of the author's apparent predilection in his citations from the periodical press.

As a sample of the author's method of making up his abstracts, the following instance is cited where the reviewer has succeeded in tracing one of his many obscure statements to its original source.

Of the auriferous gravels of "The Carolinas," he says (p. 313): "The auriferous gravel deposits are often spoken of as grits being composed of loose beds of disintegrated veins, the gravel being both rounded and angular. The origin of these deposits is recent time, even the present." This is credited in a footnote to A. G. Lock's bulky volume on "Gold" (1882, p. 155) where it appears as: "The quartz grits form loose beds made up mainly of broken down auriferous veins, in rounded and angular pieces, and resting usually upon a bed rock, which may be of almost any formation. The origin of this auriferous grit is modern, and due in great part to existing forces." These words, it appears, are only the repetition, in slightly condensed form, of those of E. Emmons in his geological report on North Carolina in 1856 (p. 129).

That such crude statements based on work done over sixty years ago should be given as authoritative, when they had long ago been superseded by Kerr's lucid explanation (*Transactions A. I. M. E.*, Vol. 8, 1880, p. 462) is not creditable to Lock and still less so to Crane.

The practice of making up a book from citations and abstracts rather than thoroughly digesting and rewriting leads to the incorporation of much matter that is not strictly germane to the subject and which is often quite unimportant or even futile. No better illustration of the faults to which this method leads can be found than is afforded by the present volume. In spite of the undoubtedly good material it contains, this is so badly arranged and so confounded with erroneous statements that it is more liable to mislead than to inform. As it stands, it reflects credit neither upon the Carnegie Institution, at whose instance and expense the work was done, nor upon those who were responsible for the choice of the one who was considered most competent to undertake so important and weighty a task.

S. F. EMMONS.

West Virginia Geological Survey. Vol. II (A) Supplementary coal report. By I. C. WHITE, State Geologist. 1908. Pp. 720, and one map in pocket.

As stated in the letter of transmittal "This is a companion volume and largely supplementary to Vol. II on coal, which was published under date of June 15, 1903." The two volumes constitute a most valuable addition to the knowledge of the coal fields of West Virginia, and the author is to be congratulated on the great amount of material he has collected, partly at his own expense and thus disseminated for the benefit of the public at large.

As noted by the author the previous report had many defects due largely to the manner in which the material had been collected and also

to its fragmentary character. The present volume is not open to the same criticism for the material is complete in almost every respect and evidently it had been well digested before it was assembled for this report.

One of the most important features of this report is the corrected correlation of the formations exposed along New and Kanawha rivers with those of the northern part of the state and of Pennsylvania. In the early days these formations were identified with the Pennsylvania formations solely on the basis of lithologic similarity and on the supposition that at every point on the margin of the field the same sequence of beds was present. On these grounds the New River series of White was regarded as Pottsville and the Kenawha series as Allegheny.

By those most familiar with the rocks this question was regarded as a closed incident until in 1893 Mr. David White began a systematic study of the fossil plants of southern West Virginia. As time progressed and Mr. White became more familiar with the fossil floras of both Pennsylvania and West Virginia it became apparent that the old correlation was in error and finally Mr. White announced that practically the whole of the coal-bearing rocks of both New and Kanawha rivers was Pottsville and comparable not to the thin section of the Pottsville of western Pennsylvania, but rather to the great thickness of these rocks in the southern anthracite basin. This conclusion was based entirely upon the evidence of fossil plants which even up to that time were looked upon by many American geologists as of little value except for museum purposes.

Naturally such a statement aroused opposition and considerable controversy, and Professor John J. Stevenson, one of the earliest authorities on the geology of the West Virginia coal fields undertook the Herculean task of reviewing all of the stratigraphic and structural evidence available to determine the standing of the case. After an almost incredible amount of work Professor Stevenson came to practically the same conclusion as Mr. David White, and the results of his exhaustive labors have appeared from time to time as brochures of the Geological Society of America.

Dr. I. C. White also carried on extensive investigations which have led him to accept the work of Messrs. White and Stevenson and in the present volume he discusses for the first time the change of correlation and endeavors in every way possible to correct the errors of the early work.

While such controversies are liable to cause irritation and bad feeling while they are in progress, they are particularly gratifying in retrospect, at least when they have been settled satisfactorily to all concerned and where the settlement has not resulted from a compromise of any sort, but from the highest grade of scientific work.

No more difficult problem can be found in American stratigraphy than the separation of the coal-bearing rocks into formations and the correlation of such formations throughout the extent of the Appalachian trough and its harmonious solution by both stratigraphic and fossil evidence is a remarkable piece of work of which any geologist might feel proud.

Possibly the most important result of this work has been to demonstrate the value of fossil plants for correlation purposes. Many still urge that while this may be true of Paleozoic plants it has no bearing on the value of Mesozoic and later floras for similar purposes. The reviewer takes exception to this view and contends that when other floras have been studied as carefully and their fields relations worked out as systematically as has been done with the Paleozoic plants equally good results may be expected.

The report in question deals largely with the geology and coal beds of the southern part of the state, a rugged region which has only recently been developed. For a long time this has been an almost impassable wilderness in which the writer of this review knows from personal experience detailed geologic work was done under the greatest disadvantages. At the present time, however, the advent of three competing railroads has stimulated the development of mines and a very complete system of prospecting by core drills so that a large amount of reliable data is now available. About seventy-five such records have been collected and incorporated in this report, so that the reader is not compelled to accept the conclusions of the author, if he is not so inclined but he can go back to the original data and draw his own conclusions.

Dr. White's report is a good index of the great advance that has been made in the last four years in the study of coal. Samples have been carefully collected and many ultimate analyses made in an endeavor to determine the actual composition of the coal and the best methods of its utilization. The Illinois Geological Survey takes the lead in such work but, as shown by the present volume, the West Virginia Survey is a close second with the Ohio and Maryland surveys also in the ranks as progressive organizations, ready to serve and assist in the development of the state's greatest mineral resources. Heretofore coal samples for analyses generally have been collected at random without any systematic method for so doing and in the reports no mention has been made of how it was done. The chemical work was restricted to proximate analyses and generally the reader was permitted to make his own comparisons and draw his own conclusions without being hampered by any facts regarding the method of work.

The volume in question shows a wide departure from the old and almost worthless method of doing chemical work. Dr. White has had

samples of coal systematically collected from the various coal beds in all parts of the state and then has had ultimate analyses made of most of these. The making of ultimate analyses is an expensive and slow process and when it is known that the present volume contains over 200 such analyses it can be readily seen that the State Geological Survey has not been idle. In this work Dr. White has followed the practice of the United States Geological Survey and as a result the analyses in his report may be directly compared with those obtained at the fuel-testing plant of the federal survey. This is to be commended, not because the plan of the federal survey is necessarily the best that could have been devised, but because the federal survey has already made and published several thousand analyses on this basis, and if the various state surveys adopt the same scheme the results are all comparable and constitute an immense mass of data which is available to all who are engaged directly or indirectly in the coal business.

Unfortunafely, the chemical analyses when tested show many discrepancies which are difficult to reconcile with the generally accurate character of Dr. White's reports. Some of the errors, are evidently due to hasty or careless proofreading. As for example, in the table facing page 166, ash in analysis no. 20 should be 6.16 instead of 5.16; in analysis no. 21, ash should be 5.38 instead of 5.28; and in analysis no. 28, ash should be 3.89 instead of 3.98; and in table opposite page 392 phosphorus in one analysis is .010 and in the other .001.

The great majority of apparent errors, however, cannot be attributed to poor proofreading but evidently are the work of the chemist. In 100 analyses checked by the writer, 23 analyses fail to foot 100 per cent., varying therefrom by amounts ranging from .09 to 6.00 per cent. Twenty analyses foot from 100.20 to 100.60. The erroneous footing is not limited to any particular analysis but is generally true of the analysis of both the air-dried sample and the sample as received.

This raises the interesting question of the degree of accuracy that is to be expected in this grade of work. It is not to be supposed for a moment that the chemical work is accurate to the fraction of one-hundredth of one per cent., especially on recalculated analyses; but are errors of one quarter or one half per cent. permissible? If the method of work as stated in the introduction conforms to that of the U. S. Geological Survey the air-dried sample is the one actually analyzed. In this work the carbon, hydrogen, sulphur, nitrogen and ash are actually determined and the oxygen by subtracting the sum of these from 100 per cent. If this method is followed it is hard to understand how totals of 100.22 or 100.46 are obtained. When the analysis of the air-dried sample is recalculated to the condition as received, errors of .01 or .02 are liable to occur in the total, but it seems to the reviewer that anything greater than .02 is not admissible.

It is to be deeply regretted that questions regarding the accuracy of this chemical work should be raised but it seems necessary to call attention to their defects, for incorrect analyses certainly are worse than no analyses at all. It is to be hoped that Dr. White or Professor Hite will explain these apparent inaccuracies, and if they are errors as appears to the writer, republish the analyses with the necessary corrections.

Lastly, Dr. White gives an estimate of the tonnage of coal yet remaining in his state which differs considerably from that already published by the federal survey. Since the writer of this review is responsible for the latter estimate, he takes this opportunity of making a necessary correction. Up to the time of publication by the federal survey no estimate had been made by any of the state geologists and consequently the present reviewer was the first to venture into a field where data were in many cases scarce and of a doubtful character and his estimates were necessarily merely guesses. Strangely enough, some of the fields in the older states were the most difficult to estimate. This was particularly true of West Virginia, Kentucky, Illinois, Iowa and Missouri. In these states many reports had been published but they dealt with limited areas and little or no information was obtainable regarding other parts of the state underlain by coal-bearing rocks.

In West Virginia this was true of the great central part of the Appalachian trough and in the region south of New River. Dr. White's report clears up some of these points and makes it obvious that the figures used by the federal survey need revision. Accordingly, the writer undertook this task with the aid of the information contained in the report. The revised estimate gives 150,000,000,000 short tons of coal as the original tonnage of the state. Dr. White's estimate figured on the same basis is as folows:

	Tons.
Good coal at present available.....	60,000,000,000
Loss in mining the above.....	30,000,000,000
Dirty coal and bone that may be available in the future	20,000,000,000
Total	110,000,000,000

The reviewer believes that this is a very conservative estimate and that the future will show that 150 billion tons is nearer the actual amount of coal in the West Virginia fields.

M. R. CAMPBELL.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LONGHLIN AND C. H. CLAPP.

METALLIFEROUS DEPOSITS.

ALUMINUM.

I Giacimenti Bauxitici di Civita d'Antino e Balssorano (Abruzzo). By C. MARTELLI. Rassegna Mineraria, Aug. 1 and 8, 1908, 5 pp.

Listed in The Mining Index of Eng. and Min. Journ., Dec. 5, 1908. Describes the occurrence and method of working several bauxite deposites in the province of Abruzzo. C.

COPPER.

Snowstorm Copper Deposit. Abstract from Prof. Paper No. 62, U. S. G. S. (By F. L. RANSOME and F. C. CALKINS.) Min. and Sci. Press. Vol. 97, No. 21, p. 701, 1908.

Describes character of ore body. L.

Ore Occurrence at Fortuna Mine, Bingham. By E. R. ZALINSKI. Eng. and Min. Journ. Dec. 19, 1908, pp. 1191–1195, with section and 3 photos.

Describes the geology and veins of Fortuna properties and the crushed zone of quartzite which has been impregnated with the sulphides of iron and copper. C.

GOLD.

Manhattan, Nevada. Eng. and Min. Journ. Nov. 21, 1908, pp. 1002–1003, 4 photos.

A short description of the district, noting three mineral belts, the southern one in granite, the middle in sedimentaries, and the northern in porphyry. The veins are gold quartz filled fissures, the present productive veins are restricted to the middle belt. The milling practiced in the district is also briefly described. C.

Sylvanite, New Mexico, the New Gold Camp. By F. A. JONES. Eng. and Min. Journ. Dec. 5, 1908, pp. 1001–1004, with 3 photos, a sketch map and cross-section.

A description of the district, and its mining history, with a short account of the geology and ore occurrence. C.

The Goldfield Type of Ore Occurrence. By R. T. HILL. Eng. and Min. Journ. Dec. 5, 1908, pp. 1096–1099, with 2 photos.

Review of recent work, notably that of Ransome in this magazine, emphasizes the difference in the "natural conditions," which distinguish the Goldfield occurrence from all others. Accepts Ransome's conclusions that this difference is due to acid and non-ferruginous vapors and solutions rather than the ordinary alkaline and ferruginous emanations. C.

A Scientific Search for a New Goldfield. By R. T. HILL. Eng. and Min. Journ. Dec. 12, 1908, pp. 1157–1160, with 6 figs.

Emphasizes the importance of the faults of the Nevada and other southwest districts, in a rather popular manner, which when taken into consideration with altered igneous rocks and fumarolic action, led in one case to the finding of a locality combining all essentials and peculiarities of Goldfield.

Camp Alunite, a New Nevada Gold District. By R. T. HILL. Eng. and Min. Journ. Dec. 19, 1908, pp. 1203–1206, with 2 maps and 2 photos.

Detailed description of the structural and economic geology of the interesting prospect located by the author, which strikingly parallels the conditions existing at Goldfield; the alunitization of the volcanic rocks of the district having been taken as the chief guide to the discovery of the deposit. C.

The San Juan Region, Colorado.—II. By T. T. READ. Min. and Sci. Press. Vol. 97, No. 20, 1908, pp. 668–672.

General accounts of the several districts and mines. L.

La Plata Mountains, Colorado. By R. H. TOLL. Min. and Sci. Press. Vol. 97, No. 22, pp. 741–744, 1908.

Gives location, topography, brief descriptions of geologic formations, ore deposits, and mines. L.

San Antonio de Poto Hydraulic Mine, Peru. By W. E. GORDON FIREBRACE. Min. and Sci. Press. Vol. 97, No. 23, 1908, pp. 780–781.

General description, including position, size, and character of deposit and the methods of working. L.

Santa Eulalia Mines, Chihuahua. By F. J. H. MERRILL. Min. and Sci. Press. Vol. 98, No. 1, 1909, pp. 37–39.

Deals chiefly with geology and ore occurrence. L.

Mining on the Mother Lode. By H. W. TURNER. Min. and Sci. Press. Vol. 98, No. 1, 1909, pp. 40–41.

One column contains summary of geology; two columns devoted to mining methods. In some mines good ore is found at depths of from 2,400 to 3,000 ft. L.

IRON.

The Clinton Iron-Ore Deposits in Alabama. By E. F. BURCHARD. Trans. A. I. M. E., Bi-Mo. Bull. No. 24, 1908, pp. 997–1055.

First part outlines stratigraphy and structure of the Clinton Formation, the character and geographic distribution of the ore. Second part gives local descriptions of the Birmingham District chiefly and of Northeast Alabama. Third part discusses the possible origin of the ore, favoring sedimentary origin. The final parts discuss relation of origin to quality and extent of ore, estimates of ore reserves, production and consumption. L.

The Clinton Iron-Ore Deposits of Stone Valley, Huntingdon County, Pa. By J. J. RUTLEDGE. Trans. A. I. M. E., Bi-Mo. Bull. No. 24, 1908, pp. 1058–1087.

I. Description of ores and associated rocks.

II. Origin: Local evidence points to replacement of blue limestone by iron as principal mode of deposition.

III. Original source of ore. Iron leached from the overlying shales. L.

A New Theory of the Genesis of Brown Hematite Ores; and a New Source of Sulphur Supply. Discussion by C. CATLETT of paper by H. M. CHANCE. Trans. A. I. M. E. Bull. No. 24, 1908, pp. 1178–1183.

Argues that the abundance of oxidized ore is largely due to concentration and hence not an accurate measure of the amount of pyrite below ground water level; that in many cases the primary ore is siderite and not pyrite; that Oriskany ores are due to infiltration from overlying slate, rather than to oxidation of pyrite in situ. L.

Iron Operations of the Birmingham District. By EDWIN HIGGINS. Eng. and Min. Journ. No. 28, 1908, pp. 1043–1049, with 8 photos and 2 figs.

Short review of recent geological work on the deposits of the district, a description of the mining operations and equipment of the Tennessee Coal, Iron and Railroad Company, of the production and character of

the coke and limestone produced in the vicinity, and of the smelting operations. The economic and industrial conditions are discussed and the advantages and disadvantages summed up as follows: Advantages, (1) Large ore reserves; (2) low cost of manufacturing pig iron; (3) adequate transportation facilities and good climatic conditions. Disadvantages, (1) Inadequate supply and inferior quality of labor; (2) limited market for the product of the furnaces. C.

Iron Operations in Northeastern Alabama. By EDWIN HIGGINS. Eng. and Min. Journ. Dec. 5, 1908, pp. 1083–1087, 9 photos.

A description of the practice in mining the thin red-ore seams and brown-ore banks of northeastern Alabama. Attalla mine of the Alabama Consolidated Coal and Iron Company taken as typical of the red-ore operations, and the Mines at Ironaton as representative of the brown-ore mines. The smelting of the ores and equipment of the blast furnaces are also described. C.

Iron Operations in the Chattanooga District. By EDWIN HIGGINS. Eng. and Min. Journ. Jan. 2, 1909, pp. 1–5, with a map, and section and 8 photos.

General discription of the mining and smelting practiced in the district. C.

LEAD AND ZINC.

Geographic Distribution of Lead and Zinc Deposits of the Mississippi Valley. By C. R. KEYES. Eng. and Min. Journ. Dec. 21, 1908, pp. 1004–1005.

Emphasizes widespread distribution of ore deposits in the Ozark region, and restriction of ore bodies to a zone whose outer border is the margin of the Coal Measures, which zone encircles the Ozark uplift, the present uplift being the result of very recent and very rapid crustal movement. Ore deposits believed to be the result of empounding of ground water at the lower ends of troughs which pitch radially down the slope of the great dome, the Carbonaceous shales acting as a dam. C.

MANGANESE.

Manganese Deposits of Moro da Mina, Brazil. By JOQUIM LUSTOSA and J. C. BRANNER. Eng. and Min. Journ. Dec. 19, 1908, pp. 1196–1197, with 5 photos.

Short description of a general nature of the deposits. C.

The Mode of Occurrence of Manganite in the Manganese Ore Deposits of the Sandus State, Bellary, Madras, India. By A. GHESE. Trans. Brit. Inst. Min. Eng. Vol. XXXV, Part 5, pp. 685–691 with 3 photos.

Short description of the mineralogical character and structure of the ore; followed by an hyposthesis, according to which the ore-deposits have been formed by the replacement of the country rock by manganese-bearing solutions derived from the adjacent rocks. L.

RARE METALS.

Tungsten Ore Deposits of the Cœur d'Alene. By H. S. AUERBACH. Eng. and Min. Journ. Dec. 12, 1908, pp. 1146–1148, with 6 figs.

Describes in detail the occurrence of scheelite in the mines around Murray, Idaho, and the mineralogy and chemistry of the mineral, with a short account of the reduction and uses of tungsten. C.

SILVER.

Las Chispas Mines, Sonora, Mexico. By R. E. RUSSELL. Eng. and Min. Journ. Nov. 21, 1908, pp. 1006–1007, with one photo.

Short article giving the history of the mines, and a description of the development, methods of operation, treatment, labor, and of the ore stealing. The account of the geology is very meager, the ore occurs in boulders, stringers, and lenses in a series of 14 nearly parallel fissure veins in rhyolite. C.

NON-METALLIC DEPOSITS.

CLAY.

China-Clay: Its Nature and Origin. By GEORGE HICKLING. Trans. Brit. Inst. Min. Eng. Vol. XXXVI, Part 1, pp. 10–35.

Article based on the investigation of china clays of Cornwall gives mineral constituents of china-clay, noting and describing particularly the kaolinite. Argues that kaolinite is not normally derived directly from decomposition of felspar, but from decomposition of muscovite, and that the kaolinite in clay is due to surface weathering and not, as has been advanced, to pneumatolysis; also that china-clay differs essentially from common clays in that it is the result of more complete weathering in situ. C.

The Clays of Arkansas. By J. C. BRANNER. U. S. G. S. Bull. 351, 1908, 247 pp., 1 pl. C.

COAL.

Supplementary Coal Report. By I. C. WHITE. West Virginia Geological Survey. Vol. II (A), pp. XIV + 720, with map. Morgantown, 1908.

Describes Great Kanawha and New River coal fields. C.

Investigations of the Coal Fields of North Dakota and Montana in 1907. By A. G. LEONARD, C. D. SMITH, A. J. COLLIER, L. H. WOOLSEY, R. W. STONE, E. G. WOODRUFF and W. R. CALVERT. U. S. G. S. Bull. 341-A. (Advance chapter of Bull. 341.) 1908, 120 pp., 7 pls. C.

Studies of Illinois Coals. Trans. A. I. M. E., Bi-Mo. Bull. No. 24, 1908, pp. 1099–1170.

Contents: I. Introduction. By H. F. BAIN. II. The Coal-Resources of Illinois. By F. W. DEWOLF. III. The Sampling and analysis of Illinois Coals. By J. M. LINDGREN. IV. The Occluded Gases in Illinois Coals. By P. BARKER. V. Mining-Wastes and Mining-Costs in Illinois. By G. S. RICE. VI. The Use of Illinois Coals for Domestic Purposes. By J. M. SNODGRASS. VII. The Smokeless Combustion of Bituminous Coal. By A. BEMENT. VIII. The Weathering of Coal. By W. F. WHEELER. IX. The Modification of Coal by Low-Temperature Distillation. By C. K. FRANCIS. X. Summary and Conclusions. By H. F. BAIN. L.

A Résumé of the Nova Scotian Coal Mining Industry for 1908. By F. W. GRAY. Can. Min. Journ. Jan. 15, 1909, pp. 36–39. C.

PETROLEUM.

Preliminary Report on the Coalinga Oil District, Fresno and Kings Counties, California. By R. ARNOLD and R. ANDERSON. U. S. G. S. Bull. No. 357, 1908. 142 pp., 2 pls. C.

S. Pearson & Son's Uncontrollable Oil Gusher. Eng. and Min. Journ. Jan. 2, 1909, pp. 7–9, with 4 photos.

Describes disastrous fire and unsuccessful efforts to save the oil of the San Diego de la Mar Well No. 3. C.

PHOSPHATES.

First Annual Report 1907–8, Florida State Geological Survey. By E. H. SELLARDS. Tallahassee, 1908. Pp. 114, with 6 plates.

Contains a sketch of the geology of the state, an account of the mineral industries, which is chiefly phosphate mining, and a bibliography of Florida Geology. C.

WATER.

Ground Water and Irrigation Enterprises in the Foothill Belt, Southern California. By W. C. MENDENHALL. U. S. G. S. W. S. Paper, No. 219, 1908, 180 pp., 9 pls. C.

Geology and Water Resources of a Portion of South-Central Oregon. By G. A. WARING. U. S. G. S. W. S. Paper, No. 220, 1908, 86 pp., 10 pls. C.

Preliminary Report on the Ground Waters of San Joaquin Valley, California. By W. C. MENDENHALL. U. S. G. S. W. S. Paper, No. 222, 1908, 52 pp., 1 pl. C.

A Preliminary Report of the Underground Water Supply of Central Florida. By E. H. SELLARDS. Florida State Geol. Surv. Bull. No. 1, 103 pp. with 6 plates and 6 figs. Tallahassee, 1908. C.

REGIONAL REPORTS.

Franklin Furnace (New Jersey) Folio. By A. C. SPENCER, H. B. KÜMMEL, J. E. WOLFF, R. D. SALISBURY and CHARLES PALACHE. U. S. G. S. Folio No. 161, 27 folio pages of text, 6 maps, and 2 Columnar Sections. C.

Some Economic Geology of Montana. By J. P. ROWE. Univ. of Mont. Bull. No. 50, Geol. Series No. 3, March 10, 1908, 67 pp.

Listed in the Mining Index, Eng. and Min. Journ., Dec. 5, 1908. Describes the locality, uses and geology of some of the natural non-metallic economic deposits of Montana. Illustrated.

The Geology and Mineral Resources of New Brunswick. By R. W. ELLS. Canadian Geol. Survey. Report No. 983, 1907, pp. 135, with map.

Part I, Physiography, pp. 7–15; Part II, Geology, pp. 17–76; Part III. Mineral Resources, pp. 77–130. Deposits of commercial value confined to non-metallic products, especially coal, gypsum, building stone, shale, and clay. L.

Hostotipaquillo and the Lerma River. By E. ORDOÑEZ. Min. and Sci. Press. Vol. 97, No. 21, 1908, pp. 705–708.

Chiefly a physiographic description of one of the most important localities in the western Sierra Madre, Mexico. Mention made of important mines. One paragraph devoted to occurrence of veins. L.

ORE DEPOSITS.

Waters Meteoric and Magmatic. Discussion by H. W. TURNER of Prof. KEMP'S paper. Min. and Sci. Press. Vol. 97, No. 24, 1908, pp. 805–806.

Continues previous discussion by T. A. RICKARD favoring deposition of ores by meteoric water. Claims that the argument of Van Hise, that cementation is a proof of a former vigorous circulation, has not been adequately met. L.

UNCLASSIFIED.

Mineral Resources 1907. U. S. G. S.

Separate advance chapters on gold, silver, copper, lead and zinc in the Eastern States; mineral waters, graphite, petroleum, stone, gas, coke, tar and ammonia at gas works; quicksilver, magnesite; summary of mineral production; and chart showing mineral production. C.

A Bibliography relating to the Geology, Paleontology, and Mineral Resources of California. By A. W. VOGDES. Cal. State Min. Bureau. Bull. No. 30, 1908. San Francisco, Cal.

Mineral Productions of California. By L. E. AUBURY, State Mineralogist. Cal. State Min. Bureau. Bull. No. 53, 1908. San Francisco, Cal.

Statistics of mineral production; maps of separate counties. L.

General Index to Publications of the California State Mining Bureau. Cal. State Min. Bureau. Bull. No. 46. San Francisco Cal. L.

On Three Contact Minerals from Velardeña, Durango, Mexico (Gehlenite, Spurrite and Hillebrandite). By F. E. WRIGHT. Am. Jl. of Sci. Dec. 1908, pp. 545–554, with 2 figs.

Description of three minerals formed near the junction of altered limestone and intrusive basic diorite, two of them, spurrite and hillebrandite, being new species. Spurrite has a composition $2Ca_2SiO_4.CaCO_3$, crystallized probably in monoclinic system and specific gravity is 3.014. Hillebrandite corresponds with the formula $Ca_2SiO_4.H_2O$, probably orthorhombic, fibrous and often in radial aggregates; specific gravity 2.692. C.

SCIENTIFIC NOTES AND NEWS[1]

R. W. BROCK, Director of the Canadian Geological Survey, was in Washington the first week in January in conference with the Federal geologists.

MR. J. KEELE, of the Canadian Geological Survey, has just returned to Ottawa from a two-year exploration trip in the region between the Yukon and MacKenzie Rivers.

J. E. SPURR went to Monterey, Mexico, the middle of January on professional work.

A MAP OF INTEREST to economic geologists and the only recent one of any large portion of the State of Maine has been issued recently in bulletin No. 33, Office of Public Roads, Department of Agriculture. It is really a lithologic map as it shows the areal distribution of the hard rock types, including limestone, shale, sandstone, trap and granite, as known up to 1908. The title of the bulletin is Road Materials of Southern and Eastern Maine, by Henry Leighton and Edson S. Bastin, U. S. Geological Survey.

ALL PUBLIC LANDS in Wyoming, Idaho and Utah believed to contain phosphate rock have been withdrawn from entry, selection and location, pending action by Congress. As soon as possible the U. S. Geological Survey will undertake a thorough classification of the lands in question and the restoration to agricultural entry of such portions as are found to contain no phosphate. This action is a result of facts brought out at the recent meeting of the National Conservation Commission. At the present increasing rate of consumption the available supply of high-grade phosphate rock in the United States will last only

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

fifty years. The necessity of restoring phosphoric acid to the farm lands of the United States will require the utilization of these vast deposits in the western States, and therefore this timely action is taken by the government.

MR. HENRY LEIGHTON, instructor in geology at Cornell University, has resigned to take a position as assistant in economic geology in the New York State Museum, Albany.

F. B. LANEY, formerly assistant state geologist of North Carolina, became assistant curator of geology at the National Museum, Washington, on January 1.

ROBERT ANDERSON, of the U. S. Geological Survey, who is spending the winter in graduate work at Stanford University, California, has recently examined the alleged oil fields of Nevada and reported adversely regarding them. He does advise the further prospecting of the asphalt deposits, however.

PROFESSOR T. C. CHAMBERLAIN, of Chicago University, has gone to China to study the physical basis of Chinese civilization, the relation of man to soil and other material resources. As the United States has been engaged recently in taking an inventory of the physical basis of our civilization in the conservation movement, so it is desirable to know to what extent the resources of China may suffice to support the Chinese people not only in their present state of civilization but in that stage of industrial development and modernized civilization to which they are looking forward. Professor Chamberlain's work is part of that of the Oriental Commission of the University of Chicago. He is associated with Dr. E. DeWitt Burton, whose object is particularly to study the conditions of education and the relations which might be established between the Chinese and Americans with profit to both.

MR. BAILEY WILLIS, of the U. S. Geological Survey, goes to Chicago April 1 to give a course of lectures at the University extending through the spring term on "Movements of the Lithosphere, their history, distribution and possible causes."

IT IS OF INTEREST to economic geologists that the papers containing inventories of our mineral resources presented at the

Conservation Conference in December were prepared by geologists of the Federal Survey. The subjects include papers on precious and semi-precious metals, iron ore, phosphate, coal, oil, gas and water. These papers containing estimates of the available supplies of these materials submitted to the Conservation Commission, have been sent to the President for transmittal to Congress. Similar inventories of other resources were prepared by other departments of the government.

PROFESSOR ALBRECHT PENCK has accepted the invitation to address the Pick and Hammer Club of Washington, Saturday evening, January 30th, and the invitation of the Washington Academy of Sciences to speak at Hubbard Memorial Hall, February 1, on "The Antiquity of Man."

AN EXHIBIT OF THE MINERAL products of the United States, similar to that made at the Jamestown Exposition, is being prepared by the Geological Survey under the direction of J. S. Diller for the Yukon-Alaska-Pacific Exposition. The collection will be on a larger scale than formerly, special attention being given to an exhibition of fuels. The exhibit will include models, transparencies, etc., together with a special exhibit of panoramic views of Crater Lake. One of the principal features of the exhibit will be a large scale map of the United States showing the distribution of our mineral resources, especially of coal and iron ores. This exhibit will be in the Federal Building.

A CARTOGRAPHIC EXHIBIT, composed of maps and diagrams illustrating the occurrence and distribution of the mineral resources of Alaska, is now being prepared under the supervision of A. H. Brooks for the Alaska building at the Alaska-Yukon-Pacific Exposition.

C. W. WRIGHT, of the U. S. Geological Survey, has taken a furlough and gone to Sardinia on professional work in lead and zinc deposits in the interest of a London mining corporation. At the request of the National Geographic Society he will take the opportunity to visit the region of the recent earthquake in southern Italy. Mr. Wright expects to be absent about two months.

C. W. PURINGTON returned to London in January on his way to Siberia to continue professional work.

AT THE INVITATION of Mr. George Otis Smith an informal conference was held at the Cosmos Club, Washington, D. C., on January 2, 1909, for the purpose of discussing the progress of geologic work and with a view to bringing about a better coördination of the various investigations now being carried on. Professor T. C. Chamberlain presided at the meeting and of those invited to attend there were present:

F. D. Adams,
H. Foster Bain,
Joseph Barrell,
R. W. Brock,
A. H. Brooks,
Samuel Calvin,
M. R. Campbell,
T. C. Chamberlain,
W. B. Clark,
J. M. Clarke,
Whitman Cross,
H. P. Cushing,
Arthur L. Day,
B. K. Emerson,
S. F. Emmons,
N. M. Fenneman,
H. E. Gregory,
Arnold Hague,
C. Willard Hayes,
J. P. Iddings,
Arthur Keith,
H. B. Kümmel,
A. C. Lane,
Waldemar Lindgren,
A. P. Low,
W. C. Mendenhall,
H. F. Osborn,
T. W. Stanton,
C. R. Van Hise,
A. C. Veatch,
David White,
H. S. Williams,
Bailey Willis.

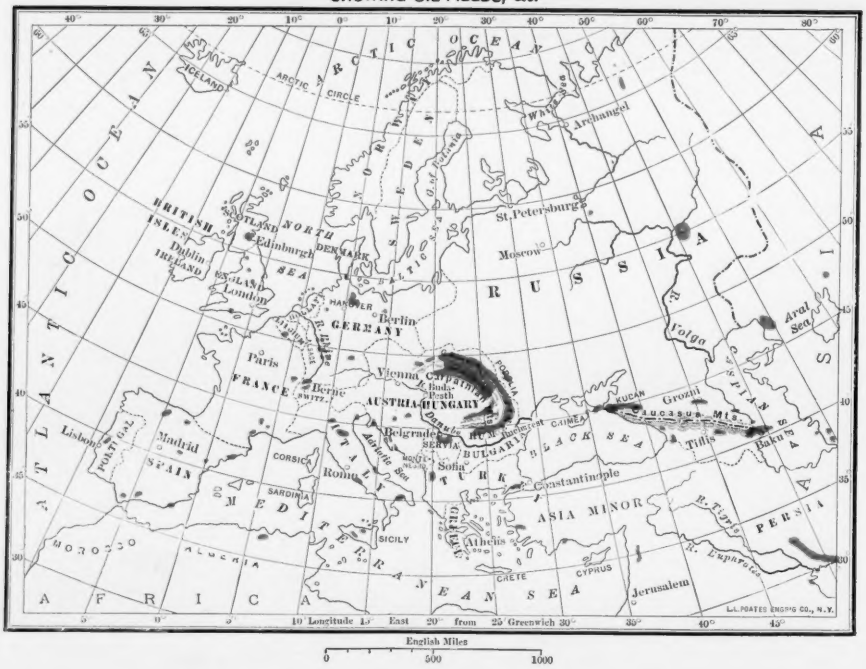
BY THE PRESIDENT'S order the Secretary of the Interior has withdrawn from entry all the public lands, embracing about 6,500 acres in the petroleum and natural gas field in northwestern Louisiana known as the Caddo oil field. This action is taken pending a careful geologic investigation by the U. S. geological Survey with a view to preventing a waste of natural gas that has been estimated at 75,000,000 cubic feet a day, or more than one twentieth of the amount of this fuel usefully consumed in the United States.

It is interesting to note that since the withdrawal of this land

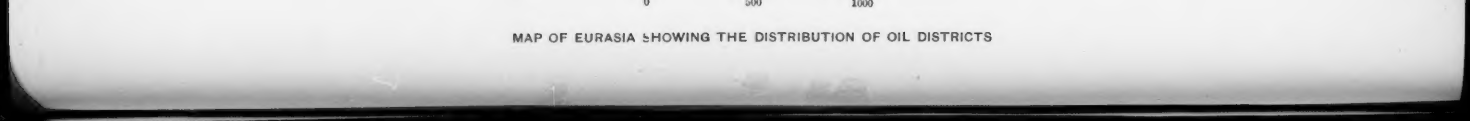
a well close to the original well has been brought in with an estimated daily flow of 10,000 barrels of oil. The presence of this oil and gas field was predicted by A. C. Veatch, of the U. S. Geological Survey, nearly three years previous to its discovery by drilling. The basis of his prediction was on geologic information obtained in an investigation of the underground water resources undertaken for the Federal Survey.

EUROPE

SHOWING OIL-FIELDS, &c.



MAP OF EURASIA SHOWING THE DISTRIBUTION OF OIL DISTRICTS



MAP OF EURASIA SHOWING THE DISTRIBUTION OF OIL DISTRICTS